

JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

Vol. 28

APRIL, 1936

No. 4

CONTENTS

Plankton Control in Morris Reservoir. By C. W. Sopp..	447
Hazards in Use of Public Water Supply System as a Ground for Electrical Circuits. By D. W. Johnson.....	458
Economics of Water Softening. By C. Maxwell Stanley.	469
North Carolina Rainfall. By Lee A. Denson.....	479
Geology of the Coastal Plain of North Carolina. By William F. Prouty.....	484
Germicidal Properties of Silver in Water. By J. Just and A. Szniolis.....	492
An Improved Odor Test on Water. By John R. Baylis and Oscar Gullans.....	507
Suspended Solids in the Foaming and Priming of Boiler Water. By C. W. Foulk.....	528
Purification Methods at New Orleans. By Carl C. Fried- richs, Jr.....	537
Report of the Secretary for Year Ending December 31, 1935.	542
Abstracts.....	545

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PLANKTON CONTROL IN MORRIS RESERVOIR

By C. W. SOPP

(Assistant Chief Engineer, Water Department, Pasadena, Calif.)

Morris Reservoir is located in San Gabriel Canyon about four miles northerly of Azusa, California. The canyon is deep and narrow, and although the axis of the reservoir is irregular, it has a general northeasterly and southwesterly trend. The maximum depth of the reservoir at the dam is 245 feet. The prevailing direction of the wind is upstream during the day and downstream at night. Inflow occurs during the winter and spring months, whereas the water level continuously recedes during the summer months when the growth of algae is at a maximum. This continued recession tends to prevent the growth of attached forms of algae around the margins. The few attached forms that have occurred have been easily killed with copper sulphate. The reservoir has been in operation two years.

The Department closely limits the growth of plankton, free-floating algae, to prevent imparting tastes and odors to the water. The water is treated with ammonia and chlorine at the dam. The chloramine thus formed probably does not eliminate the tastes and odors that are present prior to this treatment; however, it prevents chlorinous tastes caused by combination with oils in the plankton cells. There is usually a grassy or fishy odor at the aerators at the end of the transmission conduit 18 miles distant from the reservoir. These odors are more noticeable under the distribution reservoir roofs.

The seasonal distribution of algae has followed the general laws governing their growth. The diatomaceae—*asterionella*, *melosira*, and *synedra*—have occurred in the cool spring and fall months of

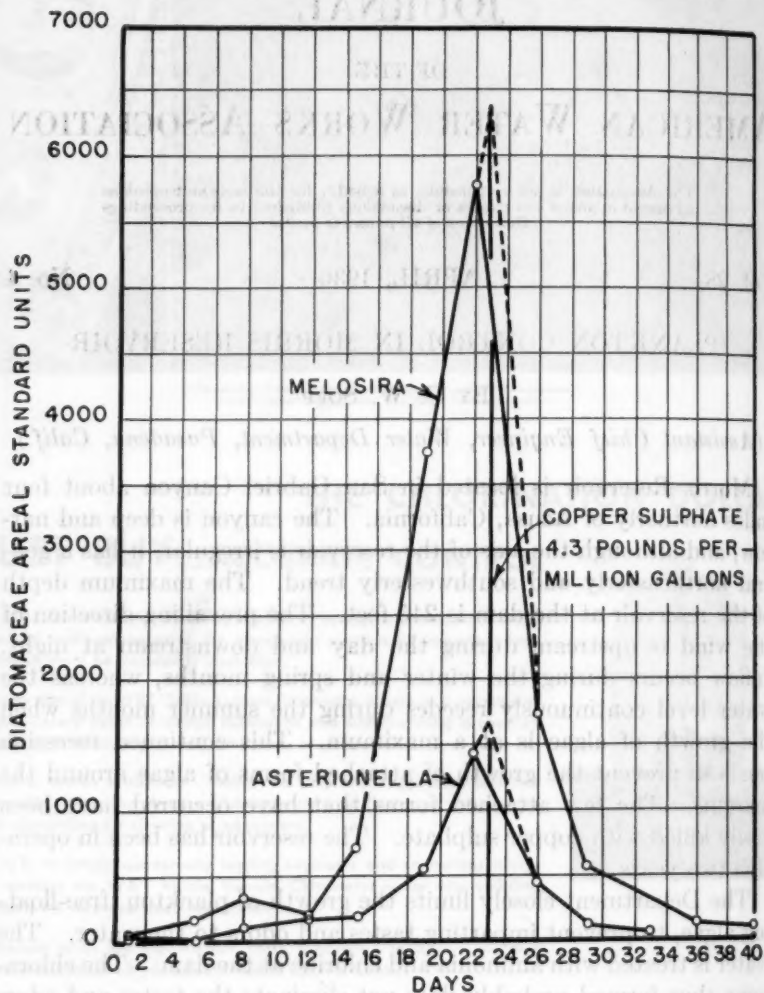


FIG. 1. MORRIS DAM. GROWTH OF DIATOMACEAE AND DEATH AFTER COPPER SULPHATE TREATMENT

March, April, November and December. The chlorophyceae—*staurastrum*, *pandorina* and *eudorina*—have occurred in the early summer months of June and July; and the cyanophyceae—*anabaena*

—have occurred late in the summer during the months of August and September. The same plankton do not occur each year, there having been a large growth of *Anabaena* during 1934 and practically none the current year.

The horizontal distribution of algae varies with the wind direction and topography of reservoir floor in relation to water surface elevation. Growths may be present only in the shallow arms or at backwater and the remainder of the reservoir be free of plankton. At times, it only has been necessary to treat the shallow backwater areas, while at other times only the deeper water near the dam has

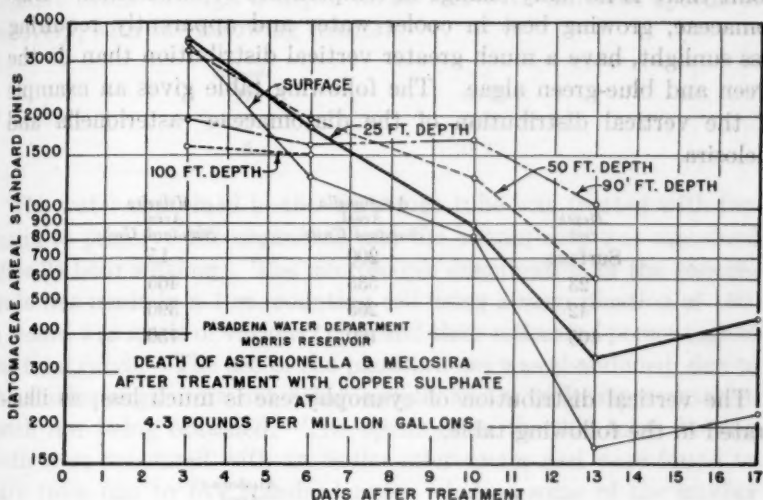


FIG. 2

required treatment. In June, 1935, the concentration of *Melosira* was 230 areal standard units in the vicinity of the dam, while at the upper end of the reservoir it was only 40 standard units. At another time there were 1088 standard units of *Melosira* at the dam and only 448 at backwater.

The vertical distribution of algae, especially *Chlorophyceae* and *Cyanophyceae*, depends largely upon the depth to which sunlight penetrates. Sunlight is necessary for photosynthesis; the process by which these organisms convert carbon, oxygen, and nitrogen dissolved in water, into food for their growth. An index of the depth to which sunlight penetrates is obtained by lowering an 8-inch enameled plate,

painted similar to a survey target, and observing through a water telescope. The depth of visibility, when the water is free from silt, has varied from $2\frac{1}{2}$ to 20 feet. The depth to which the green and blue-green algae grow is also probably influenced by the depth of vertical circulation of the surface water due to daily temperature changes and winds. The temperature is taken monthly with an electric resistance thermometer at the outlet tower at each 10 feet of depth. The data obtained indicate that the depth of marked vertical circulation is about 15 feet, from which point there is a gradual change in temperature for a depth of 20 feet, below which point there is no daily change in temperature or circulation. Diatomaceae, growing best in cooler water and apparently requiring less sunlight, have a much greater vertical distribution than do the green and blue-green algae. The following table gives an example of the vertical distribution of the diatomaceae—*asterionella* and *melosira*.

Depth feet	<i>Asterionella</i> Areal, Standard Units	<i>Melosira</i> Areal, Standard Units
Surface	200	15
23	535	465
42	265	390
105	160	150

The vertical distribution of cyanophyceae is much less, as illustrated in the following table.

Depth feet	<i>Anabaena</i> Areal, Standard Units
Surface	972
20	360
40	0

For the purpose of sampling the reservoir has been divided into sub-areas. Boundaries of the areas were determined by similarity of those factors which promote the growth of algae, such as depth, exposure to the wind where algae might be concentrated, or sheltered areas. In general this causes the reservoir to be divided into sub-areas of coves and straight runs. Curves have been drawn of the area of each reservoir sub-division for various water surface elevations to facilitate the application of copper sulphate.

SAMPLING

Water in the reservoir is sampled twice weekly. This has been found sufficiently frequent to detect the sudden increase of any organism and yet reduces the labor of sampling and analysis to a minimum.

For several months a plankton net made of 200 mesh silk bolting cloth was used. The catch was concentrated in a graduated 100 cc. centrifuge tube inserted in the small end of the cone shaped net. The net was lowered to a depth of 20 feet and recovered as rapidly as possible using a medium sized fish reel. A test was made of the relative catch through a depth of 20 feet with different speeds of recovery, with the following results:

Seconds	c.c.
19	0.07
12	0.09
6	0.12

The water contained in the centrifuge tube was treated with formalin to preserve the organisms and the concentrate was examined after 24 hour settling. The microscopic examination of the concentrate was made in a 1 cc. counting cell using a magnification of 100. A record was made of various types and their estimated percentage of the total catch. The use of the plankton net was abandoned, due to the smaller organisms not being caught and a truly representative catch not being obtained. The openings in the 200 mesh bolting cloth were measured with an ocular micrometer and were found to vary from one to five standard units, whereas some of the smaller organisms only have an area of one or two standard units. A comparison of the organisms caught in the net with those obtained from bottle samples showed that on one occasion anabaena was very small percentage of the catch, while bottle samples indicated 370 standard units. On another occasion no anabaena were found in the net sample, while the bottle sample indicated 176 standard units. An examination was made of a fine bronze wire cloth, but a 240 mesh per inch showed the size of opening to be 6 to 18 standard units. This was considered too large. A wire cloth having 325 meshes to the inch is available, and it might be satisfactory.

Present practice is to sample the water at the outlet tower opposite the gates at each 20 foot elevation and to take surface samples in

the sub-areas of the reservoir. A depth sampler made from a 3-inch brass cylinder, with a light weight valve at the top and the bottom, was constructed. The weight of the cylinder and the valves are such that the valves remain open during the downward movement of the sampler, permitting the water to pass through the cylinder, but the valves immediately close upon beginning the upward movement. Samples thus taken at various depths are transferred to clear, square 1000 cc. glass bottles. These bottles have been found very satisfactory in that they may be compactly fitted in a carrying case and the clear glass permits forming an idea of the

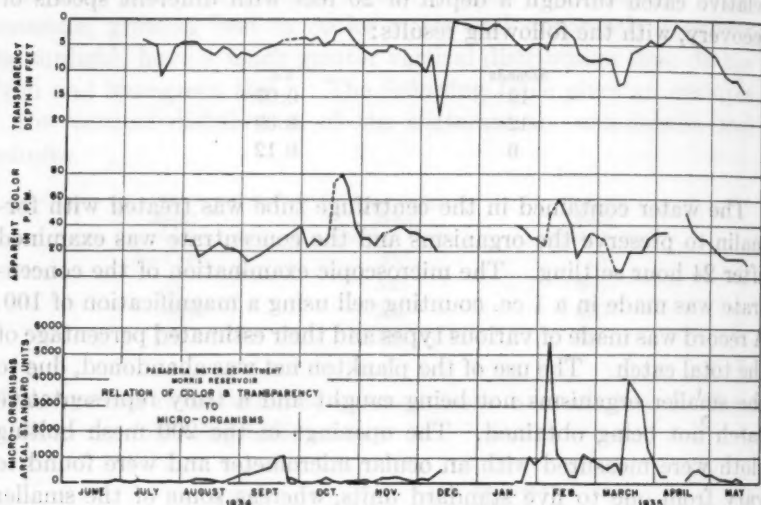


FIG. 3

color and turbidity of the water, although these tests are made separately.

In the laboratory both the Kofoid method of concentrating by filtering through paper, and the Sedgwick-Rafter method of concentrating by filtering through sand have been used. The former method has been discontinued due to the constant attention required to refill the funnels, and to permit a few cubic centimeters of the concentrate to be taken for microscopic examination. Plankton and amorphous matter stick to the filter paper and washing removes shreds of paper which interfere with the microscopic examination.

In the Sedgwick-Rafter tubes a sand of the following compositions is used for a filtering medium:

<i>Meshes per inch</i>	<i>Percent</i>
40-60	20
60-80	30
80-100	40
100-140	10

Considerable difficulty has been experienced in the finding the 60-80 sand locally. The sand is washed prior to use and tests have shown that no organisms are attached to the sand that may not be removed by two or three washings. The lower end of the tubes are upturned which retains a few cubic centimeters of the concentrate above the filter sand. This permits many samples to be filtered simultaneously with little attention and the small quantity of water retained above the sand by the upturned tube prevents the plankton from drying. Microscopic examination is made in a 1 cc. counting cell. A true measurement of the algae present in the water may be obtained by the volumetric standard unit. However, its determination is too laborious and the simpler method of determining their area by areal standard units is used. These units are determined by estimating the area of the type by observing through an ocular micrometer inserted in the eyepiece. Ten microscopic fields per sample, using magnification of 100, are examined. The total standard units of the various plankton per cubic centimeter of the sampled water is computed from their area in the 10 fields and the concentration of the samples. Amorphous matter is reported with notation as to whether it is organic or silt.

During the fall of 1934 and 1935 an unidentified form was found stratified at considerable depth at the outlet tower. It was from 2 to 6 microns in diameter, reddish-brown in color, with numerous short pointed spines radiating in all directions from a nucleus. At first it was believed that it was a form of diatom, but later tests indicated that it may have been either ferric hydroxide or an insoluble ferric compound of sulphur and organic matter. We came to this conclusion due to the fact that it could not be stained with methylene blue, indicating that it was inorganic. Chemical tests showed 0.7 p.p.m. of iron, and the fact that a somewhat similar form was produced by passing hydrogen sulphide through a solution of an iron salt was further proof of the conclusion. Its absence at great

depths may have been due to reduction to a soluble ferrous form where the dissolved oxygen was a low percentage of saturation. It has been found at a depth from 20 to 25 feet where the dissolved oxygen was about 40 percent saturation; and at a depth of 34 feet where the dissolved oxygen was 7.2 percent saturation.

CONTROL LIMITS AND METHODS

In general, in order to maintain a high quality of water, growths have not been permitted to become excessive. The limits before treatment are varied according to the type and the season. Higher concentrations are permitted for inoffensive types and for objec-

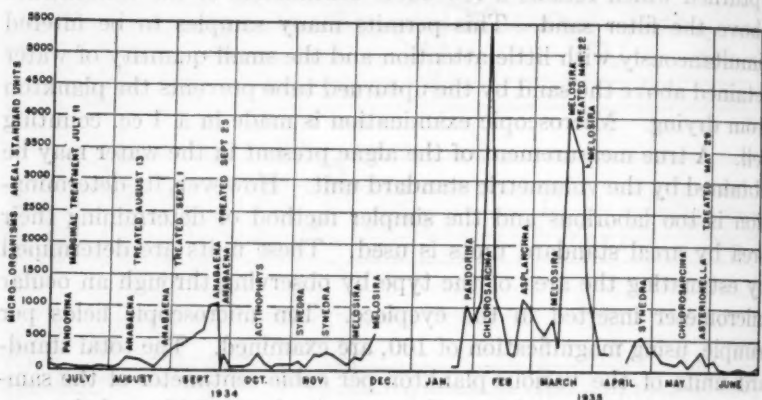


FIG. 4. MORRIS RESERVOIR. OCCURRENCE OF MICRO-ORGANISMS SHOWING PREDOMINANT TYPES

tionable types at a season when it is reasonable to expect a natural decrease in a short time. However, on occasions they have been as high as several thousand standard units. The amount of copper applied has been based upon the standards of Hale as given by Whipple. The quantity for various types is corrected for temperature, alkalinity carbon dioxide, and organic matter. It appears that experience is the best guide for western waters until further research work has been done. This is illustrated by the statement of Whipple that 83 pounds of copper sulphate per million gallons is required to eradicate eudorina and pandorina, but they have been successfully killed by quantities less than one fifth of this amount. The quantity required to eradicate anabaena, corrected for the

various factors, was computed to be 1.67 pounds per million gallons. A treatment of 2 pounds per million gallons was applied with no effect; however, they were immediately wiped out later by a treatment of 4 pounds per million gallons. The amount of copper sulphate to be applied is computed on volumetric basis for 10 or 20 foot depths, depending on the vertical distribution of the organisms, but the rate is converted to pounds per acre for convenience in application.

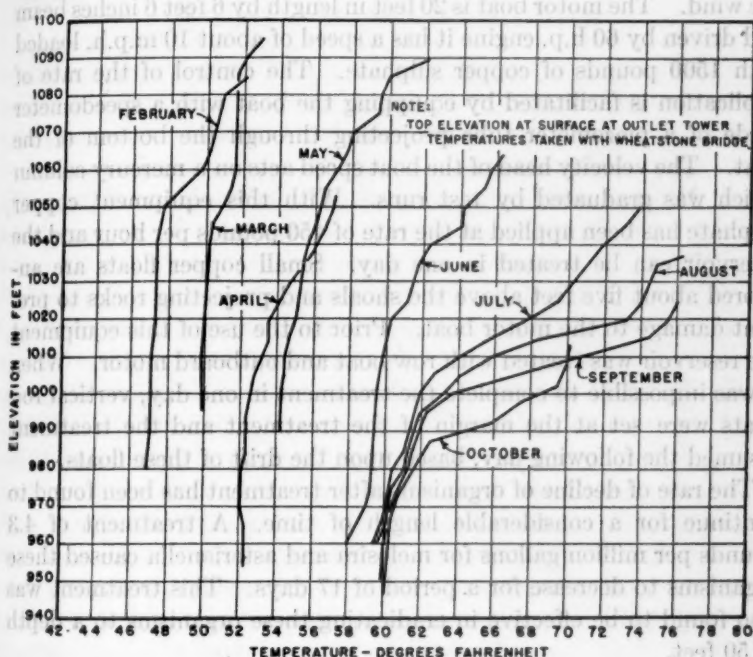


FIG. 5. MORRIS RESERVOIR. SEASONAL VARIATION OF TEMPERATURE GRADIENT 1935

Commercial crystal copper sulphate has been purchased in 450 pound barrels, but it has been found to be more convenient to purchase it in 100 pound water proof sacks. It is applied to the reservoir by means of a solution box overhanging a motor boat on each side with a storage hopper across the boat between the solution boxes. The motion of the boat causes water to enter the solution boxes, through forward projecting submerged pipes. The solution

is discharged from the rear of the boxes through perforated pipes projecting outward. The rate of application is controlled by valves throttling the admission of the water to the boxes and is checked by the rate of recession of the crystals in these boxes. The courses of the boat are parallel and back and forth across the short axis of the reservoir, being spaced at about 60 foot intervals on the assumption that the intervening area will be treated by drift and diffusion. The progress of the courses back and forth across the reservoir is against the wind. The motor boat is 20 feet in length by 6 feet 6 inches beam and driven by 60 h.p. engine it has a speed of about 10 m.p.h. loaded with 1500 pounds of copper sulphate. The control of the rate of application is facilitated by equipping the boat with a speedometer made of a piezometer tube projecting through the bottom of the boat. The velocity head of the boat speed acts on a mercury column which was graduated by test runs. With this equipment copper sulphate has been applied at the rate of 450 pounds per hour and the reservoir can be treated in one day. Small copper floats are anchored about five feet above the shoals and projecting rocks to prevent damage to the motor boat. Prior to the use of this equipment the reservoir was treated with row boat and outboard motor. When it was impossible to complete the treatment in one day, vertical rod floats were set at the margin of the treatment and the treatment resumed the following day, based upon the drift of these floats.

The rate of decline of organisms after treatment has been found to continue for a considerable length of time. A treatment of 4.3 pounds per million gallons for *melosira* and *asterionella* caused these organisms to decrease for a period of 17 days. This treatment was also found to be effective in eradicating these organisms to a depth of 50 feet.

Morris Reservoir became naturally stocked with trout, which are probably the most susceptible to copper sulphate of the fish commonly found in reservoirs. After each treatment the dead fish are recovered from the surface of the reservoir and buried. Whipple states that the maximum permissible quantity of copper sulphate to avoid killing trout is 1.2 pounds per million gallons. The reservoir has been treated at the rate of 2 pounds per million gallons without killing trout. After one treatment of 4 pounds per million gallons 5 dead fish were recovered while after another treatment of 5.5 pounds per million gallons 30 dead fish were recovered.

The Department plans to do research work on the width to which

copper sulphate solution spreads when applied from a boat, thus permitting most economical use of copper sulphate without hazard of leaving untreated areas between boat courses. Another research problem to be attacked is the rate of settlement of the copper sulphate solution and the rate at which it changes to insoluble copper hydroxide.

(Presented before the California Section meeting, October 25, 1935.)

By Dr. W. Johnson, Assistant Engineer, The City of Los Angeles, California.

This question comes to the mind of the waterworks operator almost every day as more and more ground wires are tied on to the water pipes. The electrician connects the fuse box to the water pipe; the telephone man connects on a ground wire; the radio man a ground wire; and the appliance man connects the washing machine, the range, the electric and the air conditioning. There may be as many as six or seven different ground wires connected to the water pipe in one residence. The water man almost wonders if he is in the water business or whether he is a subsidiary of the electric utility. Several years ago the water system suffered considerable damage due to the flow of stray electrical current over their pipes. This was also the experience of the gas industry in this country and still is in some of the foreign countries where the stray electric currents are very prevalent due to the poor bonding of the street railway system. One company reported that the stray electric currents were of sufficient magnitude to ignite the gas whenever a main was cut in two for a pipe. The water man remembers this trouble and having most of it behind him does not care to involve himself in another episode of electricity or physical danger to his employees or to encourage a condition that may create a hazard for the customers in service. The average water man is not a specialized electrician trained in the function of grounded circuits, electrolysis, and galvanic action. He only knows that all electrical circuits are dangerous to the general public and their wires are to be regarded with the same care and respect as a rattlesnake. The electrical companies have educated the public to this frame of mind by the use of posters, films, addresses to school children, etc. A water setter or service man cannot help but be skeptical when working on a service since he knows that there are several ground wires connected to the other end of the pipe and he has no idea what voltage these wires may carry. He does know

HAZARDS IN USE OF PUBLIC WATER SUPPLY SYSTEM AS A GROUND FOR ELECTRICAL CIRCUITS

BY D. W. JOHNSON (ASSISTANT ENGINEER, THE CAST IRON PIPE
RESEARCH ASSOCIATION, *Chicago, Ill.*)

This question comes to the mind of the waterworks operator almost every day as more and more ground wires are tied on to the service pipes. The electrician connects the fuse box to the water pipe; the telephone man connects on a ground wire; the radio man a ground wire, and the appliance man connects the washing machine, the mangle, the oilomatic and the air conditioning. There may be as many as six or seven different ground wires connected to the water piping in one residence. The water man almost wonders if he is in the water business or whether he is a subsidiary of the electric utility. Several years ago the water systems suffered considerable damage due to the flow of stray electrical current over their pipes. This was also the experience of the gas industry in this country and still is in some of the foreign countries where the stray electric currents are very prevalent due to the poor bonding of the street railway system. One company reported that the stray electric currents were of sufficient magnitude to ignite the gas whenever a main was cut in two for repair. The water man remembers this trouble and having most of it behind him does not care to involve himself in another siege of electrolysis or physical hazard to his employees or to encourage a condition that may create a hazard for the customers he serves.

The average water man is not a specialized electrician trained in the function of grounded circuits, electrolysis, and galvanic action. He only knows that all electrical circuits are dangerous to the general public and their wires are to be regarded with the same care and respect as a rattlesnake. The electrical companies have educated the public to this frame of mind by the use of posters, films, addresses to school children, etc. A meter setter or service man cannot help but be skeptical when working on a service since he knows that there are several ground wires connected to the other end of the pipe and he has no idea what voltage these wires may carry. He does know

that the wires are attached to the piping for the definite purpose of carrying excessive high voltage or amperage to the ground in order to protect the persons occupying the residence or the property itself. As an employee of the water company the practice of grounding wires to the water pipes offer only a remote protection to him.

The question of hazard may have some relation to the insurance rates charged for coverage under the state compensation laws. The rate on an electrical operator is \$4.87 and the rate on a water operator is \$1.76. In other words, the experience of the insurance company shows the electric utility to be three times more hazardous than the water utility. By the tying of the two systems together the natural tendency would be for the water utilities accident experience to increase.

A study of the severity of accidents in the various utility fields gives the following results; from the National Safety Council Figures:

Electric Utility.....	2.08
Gas and Electric.....	1.90
Telephone and Telegraph.....	1.38
Natural Gas.....	1.33
Manufactured Gas.....	0.93
Water.....	0.34
Not classified.....	0.33

This is a numerical ratio of the number of severe accidents resulting in death, total disability or partial disability to the number of man hours worked. The number of fatal accidents in the United States for 1934 was 101,139; of this number, 723 were caused by electrical shock and of this number it is estimated that 120 to 125 occurred in the home. In regard to the actual number of deaths caused by coming in contact with a water pipe, or a water pipe and a grounded secondary I was able to find only one case, the details of which were not given and it was impossible to learn if the circuit was grounded or not, only that a person was working on an electrical circuit in a basement and became involved in the piping and wiring and was killed. This line of investigation would indicate that no physical hazards of great consequence has been brought upon the water utility or the customer by the use of the water piping as a ground connection.

The term "ground" or "grounded" in the electrical industry means the connecting of a wire to the earth in such a manner as will give a good electrical contact for the flow of current from the wire through the earth back to the source of supply. The ground to be of any

value must have a very low resistance for the flow of current. A wire connected to a ground rod driven in a dry sandy soil may have a resistance of 20-100 ohms and would constitute a poor ground, while if the ground rod was driven in wet blue clay it would have a resistance of five or less ohms and would constitute a good ground. Ordinary water pipe will usually have less than two ohms resistance to ground if measured at a point ahead of the meter. The earth has a very low electrical resistance between two points after a good contact has been secured. The total resistance largely depends upon the quality of the "ground contact." The electrical industry has found it easier, more economical and better to use water pipes for ground than any other every day means.

The logical method of procedure for determining if the practice of grounding on water pipes is hazardous to life or property would be to consider the reasons for the grounding of the various circuits, the voltage they carry and the amperes drawn by the appliances, also the type of current distributed, whether D. C. or A. C.

DIRECT CURRENT

The use of direct current by the various electrical utilities is the greatest property hazard to confront the water operator. There should be a definite rule that no direct current wires are to be grounded to the water pipes. Direct current generation is decidedly on the wane, but the use is still permitted in the business sections of many cities. It is especially adapted for elevator service and of course most street car systems operate on this type of current. There are certain other classes of business that generate direct current for their own use, such as the welding industry, electro plating, battery charging, telephone companies, telegraph companies, signal wires and excitation for synchronous motors. Any complaints arising from industries of this character on account of corrosion or bad water should be given special tests for electrolysis. Cases have been reported where the piping systems of electro plating factories have failed completely from this source of trouble and have had to be replaced. Direct current is a definite hazard to all underground piping as one ampere per year will plate out 74 pounds of lead, 13-20 pounds of iron, 23-46 pounds of copper and 24 pounds of zinc. The flow of only a milliampere leaving a pipe at one point will soon cause trouble. Lead pipes or cables are especially subjected to this source of deterioration.

ALTERNATING CURRENT

The alternating current is predominant in the lighting and power field and is the type of current that we will have to deal with in the future. The electrolytic action of alternating current is only one or two percent of direct current. The electrical industry insists that there is no electrolysis hazard involved with the use of alternating current. I believe this is generally true although a few cases of trouble have appeared in the professional journals.

NEUTRAL WIRE GROUNDING

The most common wire to be grounded on the piping system is the neutral wire from the service box. This is for the purpose of protecting the circuits inside of the residence from voltage higher than the normal service rendered to the customer. The neutral wire has zero potential and the potential difference between the neutral wire and the other wire of a two wire service is 115 volts. If it is a three wire service, there will be a potential of 230 volts between the two outside wires. With the neutral wire grounded the potential should not rise above these voltages in case of the electrical failure of the higher voltage distribution system or equipment on the outside of the customers premises. In other words, the house is theoretically protected from voltages such as 2,300, 6,600 and other primary voltages.

The grounding of the neutral wire, however, has little or nothing to do with the protecting of the customer or waterworks employee from the 115 volts due to the failure of the wiring or appliances within the dwelling and it might impose a hazard on the service men or plumbers working on the line. When the electrician grounds a wire to any pipe he assumes that the pipe with all its joints, ells, unions and meter constitutes as good an electrical conductor as a copper wire. This may be true in some cases, but we cannot believe it is true in all instances. The removal of the meter would break the continuity of the circuit in thousands of homes especially the dwellings of the working class of people. These may not have gas service or a complete sanitary installation so that several piping systems can be tied together to further improve the conductivity.

The National Electric Code provides for the grounding of the neutral wire (903 A) to the water pipe on the street side of the meter so as to improve the continuity of the circuit or if the neutral is grounded back of the meter a permanent jumper shall be installed

across the meter. The code further provides that the grounds shall carry no objectionable current. They are only to serve as a safety valve to protect property or life in case of other electrical failure. The code makes no special mention of installing a jumper on a meter installed in the parkway, evidently it is supposed that the intervening pipe will make an effective ground. If this is the case they should use ground rods instead of water pipes. The service pipe is usually laid at a shallow depth and if in a dry sandy soil the intervening pipe would constitute a very poor ground. In some localities the service pipe between the house and the parkway meter would give ample contact for grounding purposes, depending upon the soil and moisture conditions.

The electric wires usually enter at the rear of the residence and the water service is usually brought in from the street, with the meter being placed either in the parkway or near the front basement wall. The electric service box is usually placed at the rear of the residence. In order to ground the neutral wire, the service box and conduit in accordance with the code, a separate wire in conduit is run from the electric service box to the pipe ahead of the water meter. The general policy for the electrician is to make the connection at the closest possible point and then to forget about the jumper on the meter. With the meter out of the circuit and no jumper the pipe virtually becomes a bare neutral, or perhaps even worse, if a service man or plumber is working on the pipe and it is called upon to function as an electrical protective device, the man will receive full force of the shock. This hazard might easily exist in a basement with a wet or damp lamp cord lying on the water pipe or defective motor windings.

The water company should enforce this rule of the National Electric Code, governing the installation of jumpers on the meter when the ground is made at some point inside the meter. This is the only protective device provided for the safety of the water employee and the plumber. When properly installed there should be no danger while changing meters.

Rule 909 f: "The point of connection of the grounding conductor to a water piping system shall be on the street side of the water meter or on a cold water pipe of adequate current-carrying capacity, as near as practicable to the water service entrance to the building or near the equipment to be grounded, in which case the piping system shall be made metallically and permanently continuous by bonding all parts within the building which are liable to become physically disconnected such as at meters and service unions." 1933 N. E. C.

GROUNDING METAL CONTAINERS

The second most common ground to the water pipe is the metal conduit and appurtenances used by the electrical industry (904 A) to carry the wire through the residence. It is required that all metal containers be grounded. This is a safety measure for the benefit of the resident as it protects the individual from shock due to poor insulation or defective appliance used by the household. It also protects the building against fire due to heavy short circuits in the wiring, although an insulation failure due to moisture or other defect may allow considerable leakage to flow through the pipe to ground. In the instance a service man working on the pipe would be subject to shock.

The electrical circuits in a dwelling are protected by fuses. The customary fuse for basement circuits is rated at 15 amperes at 115 volts. These are tested in the designing laboratories to stand $16\frac{1}{2}$ amperes continuously. This gives ample protection for the wiring and appliances used throughout the average residence. However, it does not offer a direct protection to the waterworks employee or the occupants of the residence, only in so far as it may keep defective appliances off the line. If a person touches a defective light socket or cord and has only the fuse to protect them from the other side of the circuit, the fuse would theoretically never blow. The person could be killed by less than one ampere and the fuses are designed for $16\frac{1}{2}$ amperes providing, of course, that the person's resistance was such that 115 volts would force a large enough current through the body.

GROUNDING HOUSEHOLD APPLIANCES

The grounding of certain household appliances and portable equipment is recommended by various safety agents as a means of preventing serious shock to the customers. The washing machine, the mangel, the iron, the oilomatic and the air conditioning are grounded by connecting the metal frame to the water pipe by a flexible metallic wire. Many service cords are now being manufactured with three wires so that the third wire can be connected to the frame of the appliance and the other end to the conduit which is in turn grounded to the water pipe, the function of which is to lead off any current from the frame of the appliance that may be present from poor insulation. If the neutral wire and cord makes contact with the metal frame no shock will occur, but if the hot wire makes

contact with the frame anyone touching the frame and water pipe or other ground will receive a shock. The ground wire eliminates this hazard by allowing the current to flow through it to the water pipe instead of through the person who may have touched the appliance. If the current flow is large enough the fuse will blow and kill the circuit. If the current flow is insufficient to blow the fuse the hazard will still exist on the pipe line and a meter service man or plumber working on the pipe may receive a serious shock. This possibility would be greatly reduced if the residence had gas service and a sanitary piping system in conjunction with the water service inasmuch as they would probably be electrically tied together some place in the building. The electric utility recommends this type of grounding to its customers, but it is up to the customer to install the grounds at their own expense.

ELECTRICAL HAZARD TO HUMAN BODY

The human body is not a good conductor of electrical current and under regular conditions offers a high resistance for the flow of electricity. The conductivity of the body may be changed over a wide range by the surface condition. On a cold, dry day the resistance may be 5000-10,000 ohms while on a damp, hot, sweaty day it may be only 500-1,000 ohms. The medical profession estimates that it requires 0.010 to 0.050 of an ampere to kill a person. This sounds like a very trifling amount of current—in one sense of the word it is, as most radios use ten times this amount. However, on account of the high resistance of the human body it requires a high voltage or potential to push this small quantity of current through it. If the person is dry and cold it may require six or seven hundred volts to deliver this amperage. On the other hand, if the person happens to be a hard working ditch digger with wet feet, even fifty volts may deliver the required amperage. Cases have been recorded of deaths from these low voltages when the deceased were standing in water or had by some other means reduced their resistance to a low value.

RADIO GROUNDING

The radio is universally grounded on one side and connected to the antenna on the other side. The newer sets may be operated without one or the other depending on the set and the proximity of nearby broadcasting stations. A radio set draws about 75 watts

from the lighting circuit. The flow of current over the ground wire is very small, normally one or two milliamperes and on certain sets may approach 10-15 milliamperes. The voltage carried by the ground wire varies over a wide range depending upon the internal connections of the set. It normally varies from 0 to 12 volts, although some readings of 60 volts have been noted on defective sets. The proximity of a powerful broadcasting station may build up two or three amperes on the circuit. Another feature of a radio is the small spark obtained when touching the ground wire to the pipe. This is due to the discharge of several small condensers on most sets and on some to normal operating voltage. It might constitute a fire hazard if a poor connection were made near a leaking gas meter.

TELEPHONE SYSTEMS

The telephone systems are operated on direct current and ground their equipment for auxiliary protection only, all of the conversation being carried over a metallic system. This is normally operated at 24 volts at the plant with 12 volts at the residence and draws $\frac{1}{1000}$ of a watt. If the earth is used as a part of its circuit the line is so noisy as to be useless for modern business needs. On certain party lines of four telephones the earth may be used as a part of the ringing circuit. The ringing current is usually D. C. which is interrupted at frequencies of 20, 40, 60 and 80 cycles to ring the various parties on the line. The ringing current is not heavy and is usually of short duration. Any water employee coming in contact with this type of ground wire would not be seriously injured but probably rather aggravated. The standard telephone wire in and around the residence is free from hazards.

The lead sheath of the cables carrying hundreds of small wires are grounded to carry off any stray currents which may have been picked up from other sources. The telephone company has its electrolysis problem just the same as the water and gas companies and use all means possible to protect their cables from stray direct currents. The principal hazard in connection with telephone cables lies in the fact that they may have come in contact with some other source of electrical energy of high potential and due to its being grounded through the water pipe, may carry this current on to a service pipe that may cause shock to the waterworks employees or the cables may pick up a large quantity of direct current from some outside source and by grounding the cable to the water pipe automatically

transfer the hazard to the water company. The hazard occurs at the location where the current leaves the carrying medium to the earth. The insulation within the cable may break down allowing a small leakage of direct current on to the water pipe. The telephone companies may also ground their switchboards, generators, battery sets and possibly their private switchboards to the water pipes; each of which would be a special case and require special precaution. Some systems use the earth as a part of the circuit for supplying current for the operation of their outlying switchboards.

TELEGRAPH SYSTEMS

The telegraph systems are operated on direct current. These usually maintain a potential of 135 volts and on certain systems 270 volts. The flow of current is approximately 50 milliamperes. The flow of current can, however, become quite heavy in the case of a short, ground, or other equipment failure. These circuits are regularly grounded for lightning protection only, although some railroads use the earth and rails as a combined return path for the current. There are still a few rural telephone systems using the earth for return circuit but the hazard from that source is remote.

In some cases the telegraph system is combined with the telephone system and the new teletypewriter superimposed on these; one pair of wires serving to transmit as many as 25 separate communications at one time. The grounding of these complicated systems of communication which operate on voice frequencies is beyond the scope of this paper. The water company should have some written protection in case of trouble due to grounding of circuits of this class to their water pipes.

The stock market tickers and many other signalling devices operate on direct current with certain interruptions to register the desired information at the other end of the line. These may be termed a modified form of the alternating current system as the interruptions are very minute. These circuits if grounded for a return path would cause electrolysis or if the insulation becomes defective, leakage would result. Other private and public signalling systems are often operated on D. C. currents with the same hazard of electrolysis due to insulating failures.

The flow of a few milliamperes of direct current from a water pipe will cause troublesome electrolysis and if the current is concentrated at one point, pin holes will soon be eaten through the wall and the

pipe destroyed. The appearance of a pipe that it damaged by electrolysis is exactly the same as one damaged by ordinary soil corrosion and it is practically impossible to determine the difference unless an electrolysis survey is made on the service pipe showing excess corrosion.

NEON SIGNS

The Neon electric sign has taken its place in the advertising field and has the appearance of a permanent fixture. The effect is produced by sending a high voltage through a gas filled tube. The regular 115 volts is stepped up to 15,000 volts for this purpose. The flow of current is approximately 25 milliamperes. The grounding of the transformer shell or other appurtenances of the system to a water pipe could create a serious hazard for anyone working on the pipe with a leakage in the high voltage circuit. The location of the transformer is of primary importance, if in the sign the hazard is greatly reduced, if at some other point the hazard may be increased.

LIGHTNING ARRESTORS

The grounding of large power circuits or lightning arrestors for transmission lines should not be allowed on water pipes without a written permit from the water department. Electrical substations and switching racks should provide other ground connections than the water pipes. Lightning is of such high potential that a person would not have to be touching the pipe to receive a fatal shock.

LOW ACCIDENT RECORD

With all these possible hazards involving the grounding of the electrical circuits to water pipes, we cannot help but admit that the records do not prove that serious hazards have existed. The safety reports do not uphold our assertions. The reason probably lies in the fact that two, three or more failures or operations have to take place at the same time and the mathematical probability of these occurring simultaneously is remote. Also the electrical industry is improving its protective equipment and thereby further reducing the electrical hazards.

A questionnaire sent out by one of the leading professional magazines in the waterworks field indicated that no serious personal hazards had resulted from the practice of grounding wires to water

pipes and that only slight property damage had been suffered, of which most was due to direct current.

A review of professional journals and magazines upon the subject does not disclose serious property damage other than that caused by direct current, the remedies for which are well established. Tastes and odors are reported due to this cause but the why and wherefore are still in the investigation stage. Definite conclusions have not been reached that are acceptable to all parties concerned.

Unquestionably it is a good practice for the electrical industry and offers protection for the customer and the public. The reduction of serious electrical accidents has been very marked in the last eight years and so long as the encroachment upon the water utility is no greater than at the present time, we should not with our present knowledge of the subject stand in the way of a good cause.

The water profession should, however, be the judge and the police force when it comes to the determining of what wires shall be grounded on water pipes and the manner in which they shall be installed and shall have full authority to remove any ground wire at the expense of the other party. This attitude has been expressed by the official withdrawal of its approval of the practice by the A.W.W.A. at the Cincinnati Convention in May, 1935. Until further knowledge is made available by scientific study of the subject, it is suggested that rule 909 f of the N.E.C. be enforced to the letter.

(Presented before the North Carolina Section meeting, November 5, 1935.)

ECONOMICS OF WATER SOFTENING

BY C. MAXWELL STANLEY

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No one will question the statement that there is interest in soft water and in the softening of municipal water supplies. The vast sums expended annually by individual water consumers for water softening preparations, for the installation and maintenance of individual water softeners, for cisterns, and for other devices supplying soft water are sufficient proof that people desire soft water for washing and laundry purposes. The growing number of municipal water softening plants placed in operation each year is proof that there is interest in the softening of municipal water supplies.

The softening of water may be treated largely as a problem of economics. It is the purpose of this paper to present this point of view and to emphasize the need of considering it in approaching the problem. The writer has outlined some of the points in which consideration of water softening differs from the usual problems confronting the water works man, and has endeavored to show, by typical examples, something of the fundamental factors of the problem. The writer has used data, in several instances, from other splendid papers on water softening which have appeared in *THE JOURNAL* and in other periodicals, and makes no claim to originality in the line of thought presented in this paper. Rather, it is his desire to emphasize the need of considering the problem of water softening as one of economics.

An economic problem is one in which it is possible to evaluate savings against costs in terms of dollars and cents, and to determine whether or not the net annual saving is sufficient to justify the investment.

This approach to the problem is one that is not always present in water works projects. Usually the first considerations in the supply and treatment of water are those of sanitation and health and these considerations must be satisfied regardless of cost. There is, of course, a fundamental economic approach to problems of sanitation

and health in that we have found from experience that the investment required to obtain pure water will justify itself by the elimination of disease and sickness, and, hence, of economic loss. However, such an analysis is rather remote and difficult to make, and seldom is discussed, as we have become used to demanding water supplies which are sanitary and healthful. Other water works projects have to do with the elimination of tastes and odors. Here the fundamental consideration is largely esthetic and it cannot be analyzed as an economic problem. Water works engineers are, of course, concerned with fire protection, which is more capable of a definite economic evaluation, but an analysis of water works improvements made in recent years will indicate that they are more concerned with improving the quality of water than with providing fire protection.

So when we consider the problem of water softening, we are not primarily interested in public health or esthetics. Soft water has a luxury or convenience value and it is for this reason that individual consumers, who are supplied with hard water, will spend considerable sums annually in order to soften the water or to supply an alternate source which is soft. This very fact opens the way for economic consideration of water softening in that the summation of the individual costs of softening water may be balanced against the costs of a municipal system.

This again brings a different point of view from that which is usual in water works problems. Ordinarily when a water works engineer desires to make a certain improvement, which will result in a saving, such as a change in pumping equipment, he knows that this saving will accrue directly to the municipality or other organization that is making the improvement, and, hence, that the amount saved in power bills is available to finance the improvement. But with water softening this is not true. If a city installs and operates a water softening plant, it is taking on an added burden and no appreciable saving is directly available to the city administration. Of course, there are some minor savings resulting from lower maintenance cost with softer water, from improved operation of filter plants, etc., but these are small compared to the costs involved. The savings resulting from a water softening plant accrue to the individual consumer. Hence, if he is to favor a municipal water softening plant, he must be convinced that he will be benefited by it, and the best way to prove that he will, is to consider it solely on a basis of economics. In other words, it can be shown that the sum-

mation of savings to the consumers resulting from the operation of a water softening plant will, in many instances, be considerably more than the cost to the municipality for operating and financing such a plant.

LOSSES DUE TO HARD WATER

If there are to be savings to the consumer, from where are they to come? Obviously they must come from lessened expenditures, on the part of the consumer, for items occasioned by the use of hard water. In other words, from a partial or complete elimination of the losses resulting from the use of hard water.

Some of the losses resulting from hard water are as follows:

1. Extra cost of soap and other preparations for softening water.
2. Extra expense of cisterns and double plumbing systems.
3. Harmful effects on fabrics.
4. Heat losses in hot water heaters and boilers.
5. Extra expense of operating steam boiler plants and hot water systems.

Of the items of losses listed above, the loss due to soap consumption is probably the largest, and it only is considered in this paper in setting up the savings from a municipal water system. However, before considering this item, it is well to discuss briefly the other items of savings. All of them are difficult of evaluation and require certain assumptions in order to make any analysis.

In the case of cisterns, suppose we use a figure of \$150 as representing the probable cost of a cistern complete with pump, pressure tank and extra pipe and assume fixed charges, including maintenance, at 8 percent. The annual cost of each cistern would be \$12.00, which would indicate a per capita cost of \$3.00 if the average family is 4 or of \$2.40 if the average family has 5 members. If a city of 10,000 were supplied with soft water by means of cisterns the annual cost would be \$24,000 to \$30,000. And it must be admitted that the cistern is hardly perfect with regard to cleanliness, sanitation or reliability.

In the case of the loss due to the harmful effects of hard water on fabrics, we may assume the average per capita purchase of washable linen and clothes at \$10.00 per year and assume that the life of the fabrics to be increased 10 percent due to the improved laundry conditions resulting from softer water. This means an annual saving of \$1.00 per capita or a saving of \$10,000 per year in a city of 10,000,

The scale formed in boilers and hot water heaters by hard water results in a decrease in efficiency which means a greater expenditure for fuel. It is almost impossible to make any evaluation of this without analyzing a particular case to know the percentage of heating that is done by hot water and steamboilers and the percentage that is done by hot air systems. Accordingly, no attempt is made to provide an estimate of this item.

Neither is an attempt made to provide an estimate of the increased cost of operating a steam boiler plant due to hard water, except to state that railroads estimate that the use of soft water results in a saving from \$400.00 to \$4,000.00 per locomotive per year (1).

Everyone of the losses discussed above represent potential savings in terms of dollars and cents even though some of them are difficult to evaluate.

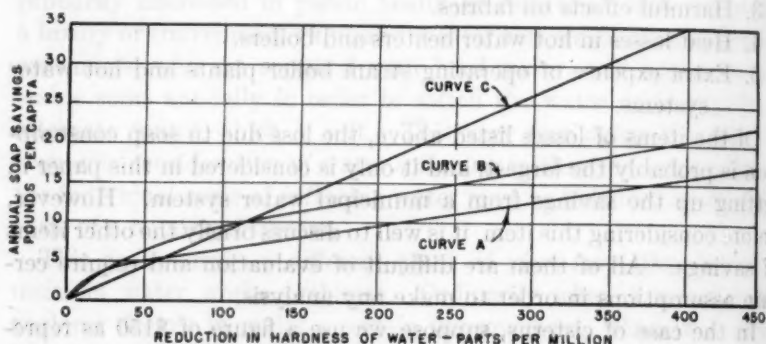


FIG. 1. SOAP SAVINGS FOR DIFFERENT REDUCTIONS IN HARDNESS

Curve "A"—Hudson-Buswell data. Curve "B"—adopted by Beard and White. Curve "C"—from Foulk's Formula.

SOAP LOSSES

The most definite loss and probably the largest, is the added cost of soap and similar preparations which are used with hard water. Figure 1 shows the results of some of the studies that have been made in this connection. Curve A of this group shows the potential savings as reported by Hudson and Buswell (2) in which they made actual surveys of retail soap sales in four cities in Illinois and Wisconsin. These cities had waters varying in hardness from 45 at Superior, Wisc. to 555 p.p.m. at Chicago Heights, Illinois. The soap consumption in pounds per capita was compared, using Superior, Wisconsin, which had the softest water, as a base.

In an extensive study of the economics of water softening in California cities Beard and White (3), Curve B was adopted. They state in their paper they have used higher soap consumption per capita than that shown by the Hudson and Buswell survey due to the fact that the Hudson and Buswell survey is concerned with retail sales only and does not consider laundries, and further, due to the fact that in their opinion the soap consumption shown by the Hudson and Buswell survey is below what may normally be expected.

Curve C is the theoretical curve of water consumption, as computed by the Foulk formula. For the purpose of this paper, we are adopting Curve B as representing the probable annual saving per capita of soap for various reductions in hardness.

SAVINGS

In order to make a comparison of the savings in cost of water softening in our study, we are taking communities of 1,000, 2,500, 5,000, 10,000, and 20,000 population and are determining the probable cost of construction and operation of plants, as well as the probable savings for these populations.

Using the Curve B, referred to above, and using an average cost of soap at 14 cents per pound, we have savings as shown in figure 2.

The next step is to determine the investment required for water softening plants for different populations. In order to do this, the first move is to estimate the annual consumption of water per capita. This has been done in figure 3. We have then estimated the capacity of the plant required, which varies from 3 times the average daily consumption in the community of 1,000 population down to 2 times the average daily consumption in the city of 20,000 population. The computed capacities of the plants for different populations are shown in figure 4. This figure also shows the estimated cost per million gallon of softening plants which varies from \$60,000 for the small plants to \$30,000 per million gallons in the larger plants. In these estimates it is assumed that the softening plant is constructed as a unit and is not built as a part of other treating processes. We can then determine the total investment required for a plant which is shown in the lower part of figure 4.

With this done, the next step is to compute the operating costs. These will consist of two types, those which are fixed and which depend upon the investment and upon the overhead costs, and those which depend upon the hardness of the water.

Fixed charges on the investment have been taken at 9 percent; $4\frac{1}{2}$ percent for interest, $2\frac{1}{2}$ percent for depreciation, and 2 percent for maintenance. To this has been added an allowance for operating labor varying from zero in the small plant (where it is assumed that

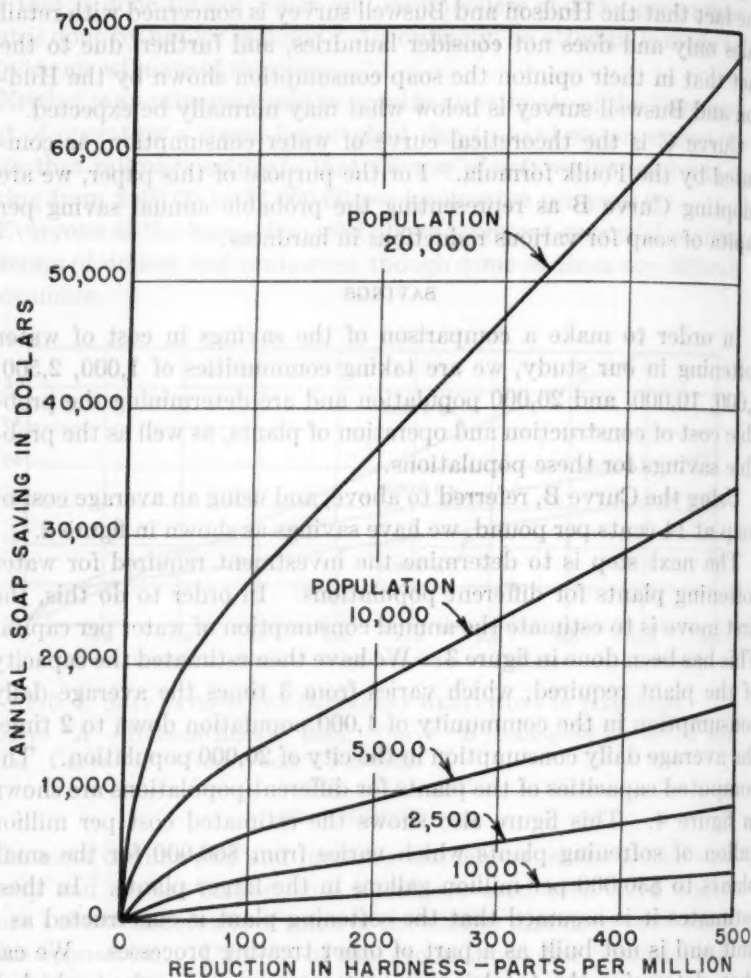


FIG. 2. ANNUAL SOAP SAVINGS

no added labor will be required) up to \$6,000 per year in the larger plant. It also includes power at 2 cents per kwh. to pump the annual consumption against a 20 foot head and it also includes an allowance for miscellaneous expenses.

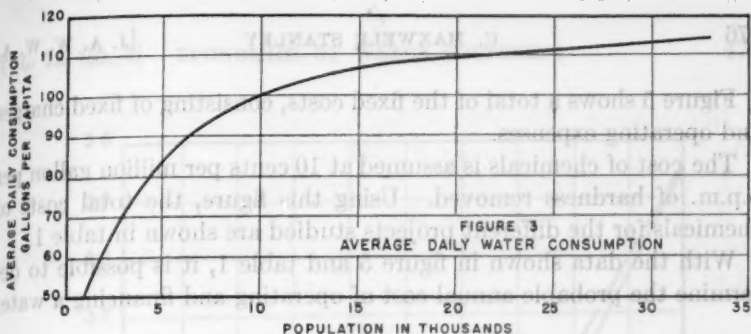


Fig. 3

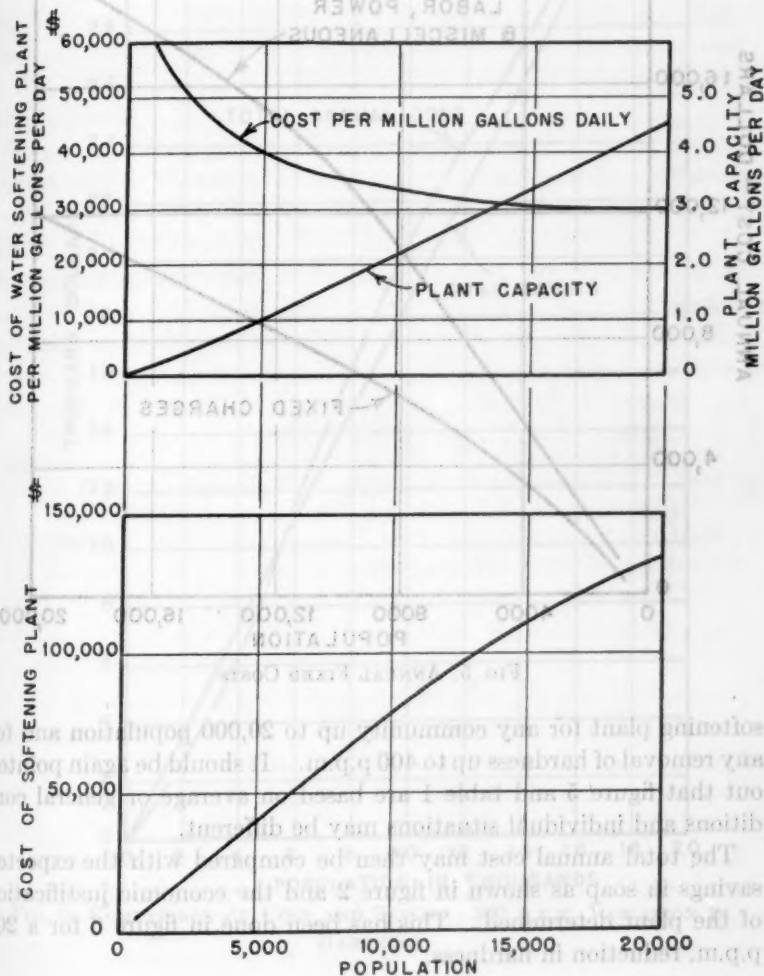


Fig. 4

Figure 5 shows a total of the fixed costs, consisting of fixed charges and operating expenses.

The cost of chemicals is assumed at 10 cents per million gallon per p.p.m. of hardness removed. Using this figure, the total costs of chemicals for the different projects studied are shown in table 1.

With the data shown in figure 5 and table 1, it is possible to determine the probable annual cost of operating and financing a water

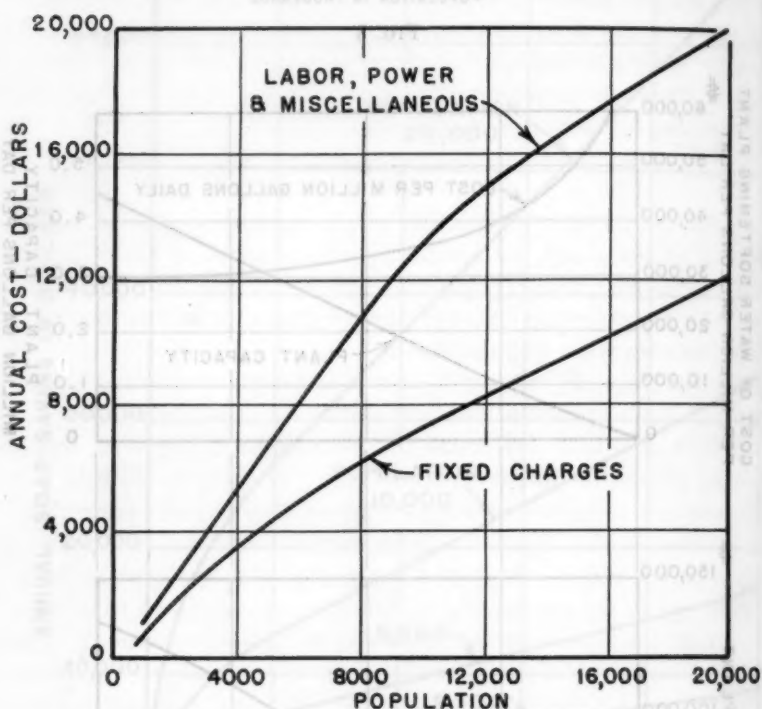


FIG. 5. ANNUAL FIXED COSTS

softening plant for any community up to 20,000 population and for any removal of hardness up to 400 p.p.m. It should be again pointed out that figure 5 and table 1 are based on average or general conditions and individual situations may be different.

The total annual cost may then be compared with the expected savings in soap as shown in figure 2 and the economic justification of the plant determined. This has been done in figure 6 for a 200 p.p.m. reduction in hardness.

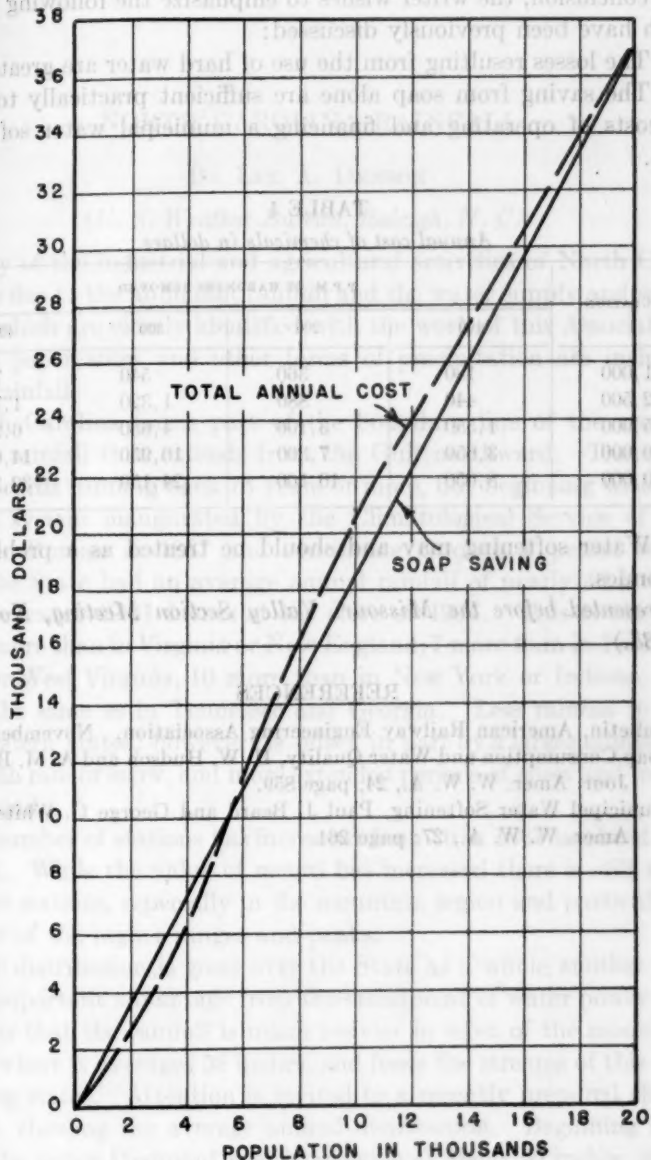


FIG. 6. COMPARISON OF COST AND SAVING. 200 P.P.M. VARIATION IN HARDNESS

In conclusion, the writer wishes to emphasize the following points which have been previously discussed:

1. The losses resulting from the use of hard water are great.
2. The saving from soap alone are sufficient practically to meet the costs of operating and financing a municipal water softening plant.

TABLE 1
Annual cost of chemicals in dollars

POPULATION	P.P.M. OF HARDNESS REMOVED			
	100	200	300	400
1,000	180	360	540	720
2,500	440	880	1,320	1,760
5,000	1,550	3,100	4,650	6,200
10,000	3,650	7,300	10,950	14,600
20,000	8,050	16,100	24,150	32,200

3. Water softening may and should be treated as a problem of economics.

(Presented before the Missouri Valley Section Meeting, November 5, 1935.)

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- (2) Soap Consumption and Water Quality, H. W. Hudson and A. M. Buswell, Jour. Amer. W. W. A., 24, page 859.
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NORTH CAROLINA RAINFALL

BY LEE A. DENSON

(U. S. Weather Bureau, Raleigh, N. C.)

Many of the industrial and agricultural activities of North Carolina are due to the abundant rainfall and the water supply and water power which are closely identified with the work of this Association. In this paper snow and other forms of precipitation are included under rainfall.

North Carolina forms part of the boundary line of the area of heavier rainfall that extends from the Gulf northward. There are some records running back 75 years or more, but beginning with the general system inaugurated by the Climatological Service of the Weather Bureau in 1887 and continuing through a period of 48 years the State had an average annual rainfall of nearly 50 inches, or to be exact 49.61 inches at the close of 1934. This is about 8 inches more than in Virginia or New England, 7 more than in Pennsylvania or West Virginia, 10 more than in New York or Indiana, and about the same as in Tennessee and Georgia. Less rainfall in the northeastern states, however, is offset in part by a larger number of days with rain or snow, and more extended periods of snow and ice on the ground.

The number of stations has increased from 30 in 1887 to about 100 in 1935. While the value of record has increased there is still need for more stations, especially in the mountain region and particularly on some of the higher ranges and peaks.

While distribution is good over the State as a whole another and highly important advantage from the standpoint of water power and supply is that the rainfall is much heavier in most of the mountain region, where it averages 58 inches, and feeds the streams of this and adjoining states. Attention is invited to a recently prepared chart, figure 1, showing the average annual distribution. Beginning at a line in the upper Piedmont near Statesville at about 50 inches, there is an increase westward to between 55 and 60 inches on the northern Blue Ridge and beyond in Avery County to the Tennessee line, and to 60 or 70 inches over the southern Blue Ridge and beyond to Clay

While distribution of water power and water supply is thus important in most of the mountain region, where it is not the streams of the and adjoining states. Figure 1, showing the average annual precipitation in the upper Piedmont region, there is an increase westward to 60 or 70 inches over the south Blue Ridge and beyond to Clay Blue Ridge and beyond to the Tennessee line, and line in the upper Piedmont region is at about 50 inches, there is a fairly regular distribution. Beginning at a recently prepared chart, which shows the streams of the and

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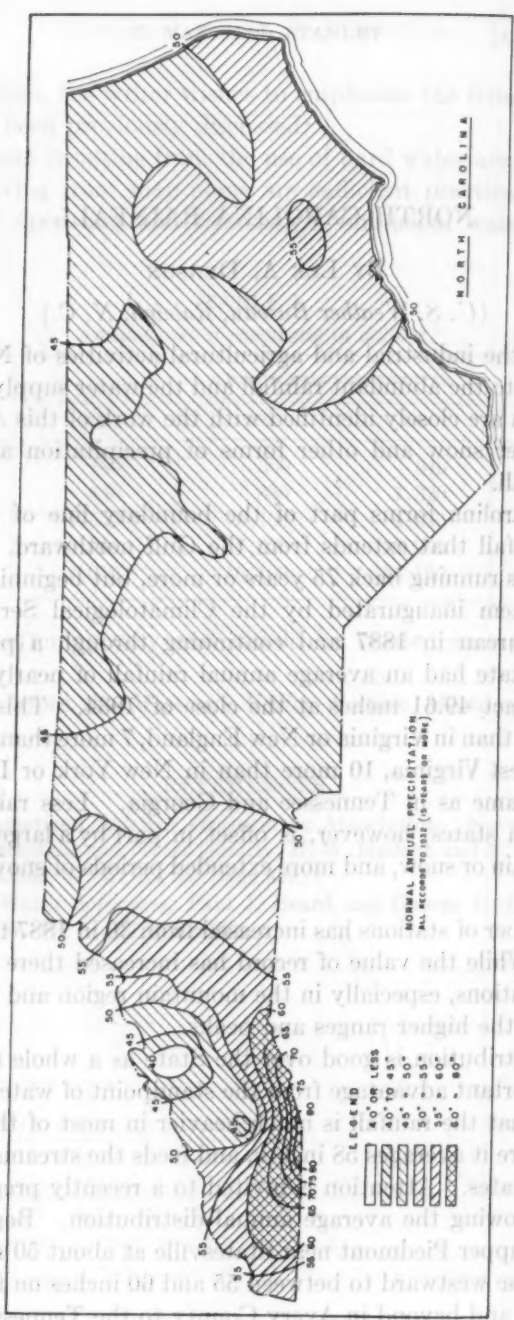


Fig. 1

County and eastern Cherokee, while the 55-inch area reaches to the Tennessee line of Cherokee, Graham and southern Swain. Over a limited area on the southern slope there are long records showing 81.18 inches at Highlands and 82.42 at Rock House, Macon County, which are heavier than in any other part of the country except on the North Pacific coast. But there is a sharp decline to about 40 inches in the closed-in valleys of the cross ranges between the Blue Ridge and Great Smoky mountains, as in the lower French Broad, and other parts of section from northern Jackson County to the western part of Yancey. These lines have been carefully prepared, but are partly estimated and may be subject to some revision when more records become available. The moisture laden winds from the Gulf and South Atlantic coasts are uplifted, cooled, and have their moisture condensed and largely exhausted in passing over the moun-

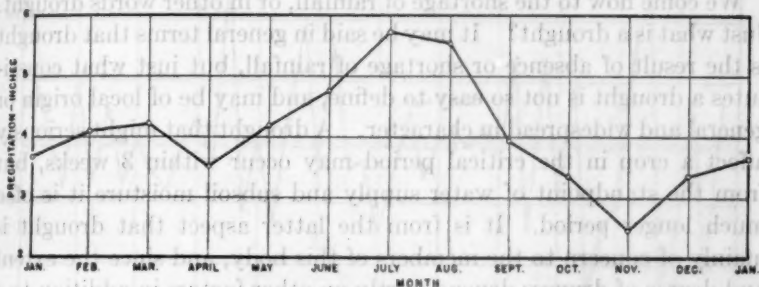


FIG. 2. AVERAGE MONTHLY PRECIPITATION—NORTH CAROLINA

tain heights. They then descend to less elevated and rather inclosed areas, such as the lower French Broad, in comparatively dry form. Part of the rainfall, however, especially in the summer months, comes from local showers and thunderstorms due to local influences and are only indirectly connected with the mass movement of air over the mountain region. In the area of heaviest rainfall there is an abrupt southern slope above 3,000 feet overlooking portions of Georgia and South Carolina, and within a short distance of the Rock House Station there is a nearly perpendicular drop of 600 feet. The Highlands station is 7 miles west-northwest near the crest of the ridge. It is estimated that the rainfall along this portion of the Blue Ridge is about 70 to 75 inches or more for a distance of 25 miles.

In most of the Piedmont, and part of the coastal plain, the rainfall varies from slightly under 45 to about 50 inches, while on that

part of the lower coast section from Pamlico Sound, Carteret and Onslow counties northward to the western end of Albemarle Sound there is an increase to between 50 and 55 inches with a small area near New Bern of about 56 inches.

In figure 2, on annual variation, the outstanding wet years of 60 inches or more are found far apart in 1901 and 1929, and the dry years of less than 40 inches 1925, 1930 and 1933 within the last ten. And yet within the last ten years the most remarkable change is shown in the drop from 62 inches in 1929 to 38 inches in 1930. Such a change and the general appearance of the graph tends to point out that a much longer record will be required to show definitely the trend of rainfall.

DROUGHT

We come now to the shortage of rainfall, or in other words drought. Just what is a drought? It may be said in general terms that drought is the result of absence or shortage of rainfall, but just what constitutes a drought is not so easy to define, and may be of local origin or general and widespread in character. A drought that might seriously affect a crop in the critical period may occur within 3 weeks, but from the standpoint of water supply and subsoil moisture it is of a much longer period. It is from the latter aspect that drought is mainly of concern to the members of this body, and since the extent and degree of dryness depend partly on other factors in addition to a deficiency in rainfall, such as the condition of subsoil moisture at the beginning of a dry period, the texture of the soil and its ability to store and hold water with least possible evaporation, remarks will be confined to shortage of rainfall.

We find a shortage of 6 inches or more for the State as a whole in 1904, 1911, 1921 and 1933, and the outstanding shortages of 12 and 6 inches in 1925-26 and 11 and 6 in 1930-31. It is generally admitted that the deficiency in 1925-26 was far more severe than in 1930-31, and probably this was due in part to carry over of increased subsoil moisture from the wet year of 1929. The following special statement on rainfall shortage has been prepared for your information from selected stations at Asheville, Charlotte, Raleigh and Wilmington:

1. Greatest number of days without a measurable amount of rainfall: Asheville 26, Charlotte 40, Raleigh 29, Wilmington 42.
2. Periods of 60 days or more in which the total rainfall did not

exceed 1.00 inch: Wilmington once in 5 years, Asheville once in 8 years, Charlotte and Raleigh once in 12 years. Only one of the periods occurred in summer, that at Asheville, in the notably severe drought of 1925 in that part of the State. There were 3 at Wilmington in winter and 2 there in spring; all others occurred in autumn which is the season of least rainfall. These periods are from actual records, but are subject to some modification when linked up with subsoil moisture and streamflow, as it not infrequently happens that a considerable rainfall occurs immediately preceding a dry spell.

Figure 3 on monthly averages is interesting in that it would seem that nature is assisting in the distribution, especially in the growing season and harvesting season. By referring to figure 3 you will see

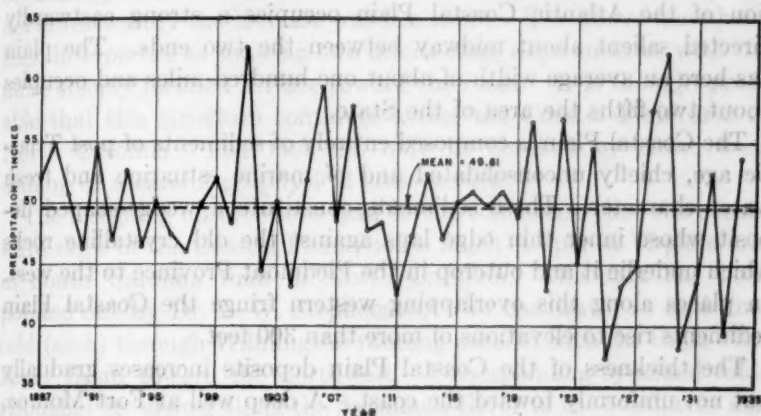


FIG. 3. AVERAGE ANNUAL PRECIPITATION—NORTH CAROLINA

that the rainfall increases as winter comes on and that there is a pick up in ground supply in the dormant season until March. Then there is a drop of $\frac{3}{4}$ of an inch in April or planting time when less rain is needed. From May to July there is an increase through the period of cultivation and July and August have the greatest amounts during development and maturity of crops, finally followed by a decline through autumn when dry weather is needed for harvesting. This is also generally favorable from the water supply standpoint, although no doubt you would readily exchange some water over the dam in February or March for an increased supply in October and November.

(Presented before the North Carolina Section meeting, November 4, 1935.)

GEOLOGY OF THE COASTAL PLAIN OF NORTH CAROLINA

BY WILLIAM F. PROUTY

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The Atlantic Coastal Plain is both a well marked geological and physiographic province extending from Cape Cod on the northeast to the point of Florida on the southwest. The North Carolina portion of the Atlantic Coastal Plain occupies a strong eastwardly directed salient about midway between the two ends. The plain has here an average width of about one hundred miles and occupies about two-fifths the area of the State.

The Coastal Plain is composed entirely of sediments of post Triassic age, chiefly unconsolidated and of marine estuarine and fresh water character. These sediments constitute a wedge-shaped deposit whose inner thin edge laps against the old crystalline rocks which underlie it and outcrop in the Piedmont Province to the west. In places along this overlapping western fringe the Coastal Plain sediments rise to elevations of more than 300 feet.

The thickness of the Coastal Plain deposits increases gradually but not uniformly toward the coast. A deep well at Fort Monroe, Virginia, reached the crystalline rock floor of the Coastal Plain at a depth of 2240 feet, giving an estimated average slope oceanward of about 37 feet per mile. A deep well at Summerville, S. C., about 57 miles distant from the inner edge of the Coastal Plain, reached the crystalline rock floor at a depth of 2450 feet. This gives an average slope of 43 feet per mile for the basement rock in this area, which is a little greater than that in the Norfolk area.

In the deep well at Havelock, North Carolina, near Beaufort, the crystalline floor was reached at a depth of 2318 feet. As this locality is about 90 miles from the inner edge of the Coastal Plain, the average dip must be in the neighborhood of 26 feet per mile. Wilmington is 83 miles from the crystalline rock outcrop, but here a well 1109 feet deep reached the basement rock. This gives a general slope of the Coastal Plain floor, when surface elevations are considered, of only 14 feet per mile in the Wilmington area. From Wilmington on

to the coast the average dip of the foundation is nearly twice as steep as from Wilmington inland, as shown from the measurements in the Fort Caswell deep well at the mouth of the Cape Fear River. This increased gradient of slope of the basement rocks in the near coast area, suggested in the Wilmington and Fort Caswell wells has recently been substantiated by the results obtained from a magnetometer cross-section of the Coastal Plain in South Carolina made by members of the Geology Department of the University of North Carolina.¹ The crystalline rocks contain a higher percentage of magnetic substances than do the Coastal Plain sediments. The magnetic intensity should increase away from the coast rather uniformly if the slope is uniform. From Myrtle Beach to about seventeen miles northwest of Conway the increase was found to be rapid. From this point northwestwardly the increase was less rapid. The above facts have been interpreted as showing two intersecting slope surfaces with the more steeply inclined surface toward the coast. It is thought probable that this structure continues across the Coastal Plain area of North Carolina. This fact can only be checked by either deep drilling or a careful geophysical cross-section.

The foregoing observations lead to the conclusion that the oceanward slope of the Coastal Plain floor is much steeper in Virginia and in South Carolina than in North Carolina. This fact has been pointed out by Dr. L. W. Stephenson,² who has drawn an anticlinal fold (arch) through Wilmington running parallel with the Cape Fear River Basin toward the northwest. Corresponding synclinal folds (troughs) are shown along the Savannah River to the southwest and the Norfolk area to the northeast (fig. 1). This warping must have occurred in post-Cretaceous time since the Cretaceous sediments are brought much nearer to the surface in the Wilmington-Myrtle Beach section than elsewhere along the middle Atlantic area. The cross-warping of the Coastal Plain and the probable steeper slope of the near ocean portion of the buried crystalline floor, as suggested by the Wilmington and Fort Caswell wells and by the magnetometer cross-section in the Myrtle Beach-Conway area, all lead to the conclusion that the basement is far from regular in its general attitude.

When we add to these facts the possibility of buried Triassic fault

¹ G. R. MacCarthy, W. F. Prouty, and J. A. Alexander, Jour. Elisha Mitchell Sci. Soc., 49: 1, 1933, pp. 20-21.

² Structural Features of the Atlantic and Gulf Coastal Plain, Bull. G. S. A., 39, 1928, p. 179.



FIG. 1. SHOWING THE ATLANTIC COASTAL PLAIN AND THE PRINCIPAL AXES OF
WARPING

After Dr. L. W. Stephenson

basins, as the one recently traced into North Carolina from the Florence South Carolina area by magnetometer studies, we realize the necessity of much careful investigation before we can be reasonably sure of the depth of the buried crystalline floor of the Coastal Plain. The structure and geological conditions of the area are com-

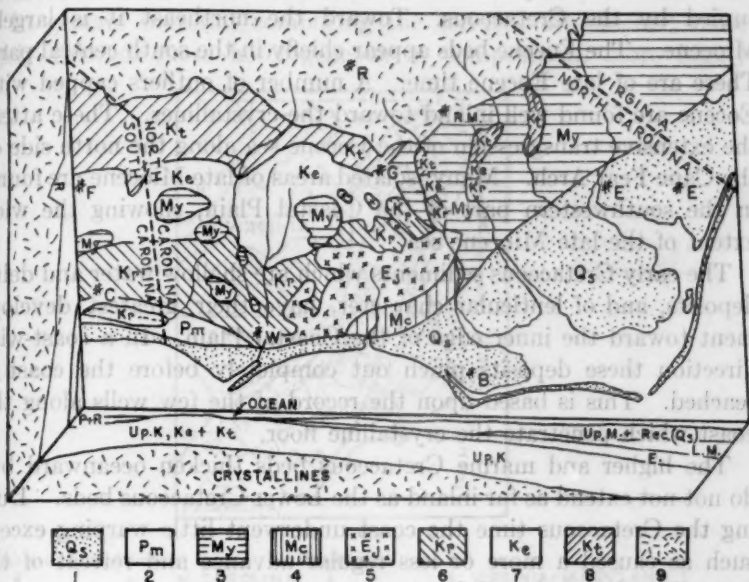


FIG. 2. 1, Quarternary, Coastal and estuarine sand and gravel; 2, Pliocene, Waccamaw marl in North Carolina; 3, Miocene, Yorktown of Virginia. Includes the Yorktown and the St. Marys as formerly mapped in North Carolina and also the Duplin marl of southeastern North Carolina; 4, Miocene, Calvert of Maryland and Virginia Trent in part of North Carolina map of the Coastal Plain, 1912; 5, Eocene, Jackson Group, in part the Castle Hayne of North Carolina as mapped in 1912; 6, Cretaceous, Ripleyin age, Peedee formation of North Carolina; 7, Cretaceous, Eutaw age, Black Creek formation of North Carolina; 8, Cretaceous, Tuscaloosa age, Mapped as Patuxent in North Carolina map of 1912; 9, Precambrian and younger metamorphics and igneous rocks of the Piedmont area and the Coastal Plain floor.

bined in the block diagram (fig. 2) which shows on the southwest end the location of the Florence Triassic trough, the character of the basement slope and the pinching out of the Lower Cretaceous beds. The front elevation gives the Cape Fear Arch and the sub-ocean distribution of the Coastal Plain formations, while the top of the block gives

the distribution of the formations according to the lately published U. S. Geological Survey map, as they would appear without the surficial terrace deposits.

The geological map of the Coastal Plain of North Carolina shows a marked difference in the character of the formations in the northeast and southwest parts. In the southwest most of the area is occupied by the Cretaceous. Toward the northeast it is largely Miocene. The Eocene beds appear chiefly in the south central part. These are of late Eocene time. A number of outliers capped with Eocene are found well inland toward the crystallines. These attest the extensive transgression of the Eocene sea along the north side of the Cape Fear Arch. Many isolated areas of late Miocene are found in the southwestern part of the Coastal Plain, showing the wide extent of the late Miocene sea.

The early Cretaceous sediments which are shallow water and delta deposits, and of lenticular character, have their greatest development toward the inner edge of the Coastal Plain. In a coast-wise direction these deposits pinch out completely before the coast is reached. This is based upon the record of the few wells along the coast which penetrate the crystalline floor.

The higher and marine Cretaceous beds thicken oceanward but do not extend as far inland as the Lower Cretaceous beds. During the Cretaceous time the coast underwent little warping except such as caused a more or less regular advance and retreat of the coast line along a broad front.

The post-Cretaceous (Eocene) warping³ of the Coastal Plain which created the Cape Fear Arch caused the later formations, and especially the early and middle Miocene, to accumulate in the down-warped areas in greater thickness and continuity than in the arched area. In late Miocene time the sea covered a large portion of the North Carolina Coastal Plain. Faunal studies,⁴ however, seem to show that there must have been at least a current barrier separating the Yorktown deposits on the northeast from the Duplin marl deposits on the southwest along a line running roughly west from Beaufort, since the sediments to the southwest are of warm water character and those to the northeast of cold water character.

During Pliocene and Pleistocene time the sea made several rapid advances and retreats across the Coastal Plain country. Each of

³ L. W. Stephenson, Bull. G. S. A., 39, 1927, pp. 887-899.

⁴ W. C. Mansfield, Jour. Wash. Acad. Sci., 19: 13, 1929.

these incursions left well developed marine terraces with a veneer of shallow water deposits. According to B. L. Johnson:⁵ "These terraces are separated by well defined seaward-facing scarps rising one above the other from sea level to elevations of over 400 feet along the eastern edge of the Piedmont Plateau. Old and higher terraces are more dissected.

"In general material composing the terraces are thicker, more highly colored, more heterogeneous in composition, more highly

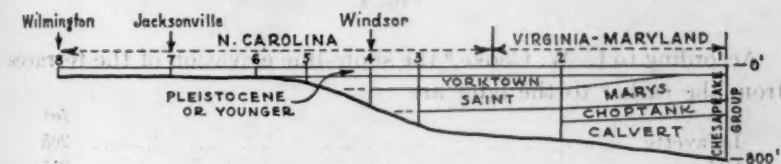


FIG. 3. MAP AND CROSS SECTION, BY W. C. MANSFIELD, SHOWING THE DISTRIBUTION AND RELATION OF THE MIOCENE SEDIMENTS IN NORTH CAROLINA, VIRGINIA AND IN MARYLAND

cross-bedded and contain a larger percent of pebbles and boulders of the crystalline rocks near the Piedmont border than farther eastward.

"Seaward the material becomes finer, the deposits thinner, and the coloring less brilliant until in the lowest terrace the sandy loams are gray or mottled with a small amount of yellow and grade down into interstratified bluish quartz sands, and bluish to drab clays. Lowest terrace poorly drained."

⁵ Vol. III, Coastal Plain of North Carolina, Pt. I, 1912.

Figure 4 shows the distribution of these terraces which are of especial interest because the terrace materials blanket much of the surface.

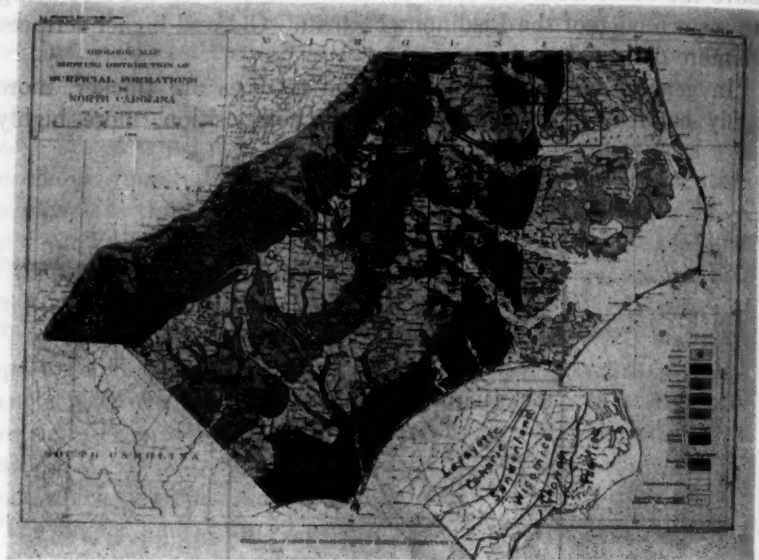


FIG. 4

According to C. W. Cooke,⁶ the shore-line elevation of the terraces from the earlier to the later are:

	feet
Lafayette	265
Coharie	215
Sunderland	160
Wycomico	95
Chowan	65
Pamlico	25

Between the building of each terrace the ocean seems to have completely withdrawn from the Coastal Plain area. Since the building of the terraces occurred during glacial time it seems probable the successive meltings of the ice caps during that time caused the flooding. There must have been in addition a general elevation of the coastal country taking place at the same time or else a sinking of ocean basin in some locality.

⁶ Correlation of Coastal Terraces, Jour. of Geol., 38: 7, 1930.

The general character of the Coastal Plain materials and their approximate thickness and correlation is shown in figure 4.

Recent studies⁷ of the Coastal Plain formations of North Carolina have necessitated several radical changes in mapping and in correlation. The St. Marys formation as mapped in North Carolina in 1912, has been found to be of the same age as the typical Yorktown of Virginia. The true St. Marys has no mapable outcrop in North Carolina, but it underlies the Yorktown for a considerable area in the northeastern portion of the North Carolina Coastal Plain. The Trent formation formerly thought to underlie the Castle Hayne of Eocene age proves to be of early Miocene age and the recently published geological map of the United States by the U. S. Geological Survey shows the Trent as the Calvert (lower Miocene) farther toward the coast than previously shown and between the coast and the Castle Hayne outcrop.

When considering the geology and structure of the Coastal Plain of North Carolina, one is impressed by the lack of regularity in the thickness, character and distribution of the formations. The dip of the crystalline floor is made uncertain by the differing slopes of its peneplaned surface as well as by warping, trough faulting and valley and hill formation by ancient erosion. These irregularities of the crystalline floor are continued in the Coastal Plain sediments as the result of warping, sedimentary lensing and unconformities.

There is great need of detailed geological work in the North Carolina Coastal Plain. A topographic map of the basement rock could be made with suitable geophysical instruments. The Department of Geology, University of North Carolina, is contemplating starting such work. It is possible also that the depth of the more important water bearing horizons could be determined by geophysical instruments. The detailed correlation of Coastal Plain formations should be undertaken. This can best be accomplished by sedimentary studies of mechanical, chemical and microscopic character. It has recently been found possible to correlate a number of the formations by their lime and bond contents.

(Presented before the North Carolina Section meeting, November 13, 1934.)

⁷ A. A. Olsson, *Bul. Am. Paleont.*, 28, 1917, pp. 155-163.

W. C. Mansfield, *Jour. Wash. Acad. Sci.*, 19: 13, 1929.

L. B. Kellum, *Prof. Paper U. S. G. S.*, 143, 1926.

J. A. Cushman and E. D. Cahill, *Prof. Paper U. S. G. S.*, 175 A, 1932-3.

GERMICIDAL PROPERTIES OF SILVER IN WATER

By J. JUST AND A. SZNIOLIS

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The outstanding germicidal properties of certain chemical compounds of heavy metals have been long known and used both in medical treatment and in industry. Compounds of copper, mercury, zinc, silver and other similar metals are used in the preparation of germicidal or preservative solutions. The concentration of such solutions varies considerably and is sometimes high. It is also generally known that compounds of heavy metals are poisonous to the human organism.

Regardless of the latter fact, however, when searching for new and better means of disinfecting drinking-water, attention has been paid to the germicidal properties of heavy metals, especially to those of copper and silver, on the assumption that if suitable doses are used the required germicidal effect in water will be attained without the poisonous properties of the metals affecting the human organism.

The presence of silver in food articles is prohibited both by law and also by medical practice. Hence arose the necessity to study thoroughly the whole problem and, on the basis of researches and observations, to revise our attitude towards the presence of silver as a heavy metal in water.

HISTORICAL DATA

The Sanskrit collection of medical lore contains the first notions about the use of copper and silver to improve the quality of water. In the "Oustruta Sanghita," a collection of medical lore in Sanskrit, probable date 2000 B.C., Chapt., XIV, verse 15, appears this instruction: "It is good to keep water in copper vessels, to expose it to sunlight, and filter through charcoal." In the "Negrund Bhusan," a collection of medical maxims from the "Ayura Veda," the earliest Sanskrit work on medicine extant, of about the same date, in the chapter on water, in the last sloke but two, it is directed to treat foul water by boiling and exposing to sunlight and by dipping seven times

into it a piece of hot copper, then to filter and cool in an earthen vessel (2).

Herodotus describes in the following way the action of silver on water (History, Vol. I, Klio, Chpt. 188): "When the Great King was starting out on a war he used to take with him a supply of corn and also of water from the river Choaspes which flows near Suza; the King never drank any other water but that of this river. He could thus go wherever he wished, being followed by waggons carrying boiled water in silver cisterns." The above quotation refers to the Persian King Cyrus who lived about 2,500 years ago.

Neither the authors of Sanskrit medical lore nor King Cyrus realized the part played by a heated piece of copper or by a silver cistern. This practical knowledge was obviously quite forgotten in later times and only towards the end of the XIXth century some information appears about the germicidal properties of small quantities of silver.

In 1880 the Swiss botanist Carl von Nägeli observed the disappearing of algae in water which was in contact with copper or silver or to which small quantities of the salts of these metals had been added. C. v. Nägeli experimented on *Spirogyra* and showed that they could not live in water which contained silver nitrate even in as small a concentration as 1 to 100,000,000. Nägeli did not think that such an extremely diluted solution of silver could produce a chemical effect on bacteria. He was thus led to form his hypothesis of *oligodynamic* properties, i.e. of specific germicidal properties of extremely small quantities of silver. Nägeli's experiments were repeated by Saxl, Thiele, Wolf and others. They have all given the same result, namely, that bacteria are also affected by the oligodynamic action of silver. The whole process and the results reached were surrounded by a certain mystery expressed in the word "oligodynamic," for it was believed that it is merely the presence of silver that acts on bacteria. Later on Salus, Söllner, Freundlich expressed the opinion that the oligodynamic properties are a result of chemical properties, i.e. that bacteria are killed owing to the chemical action of silver. In confirmation of their point of view, Freundlich and Söllner have shown that the body of algae destroyed in an oligodynamic way contained silver.

It should be added that the definition "small quantities of silver" is very inaccurate from the chemical point of view. For instance, it has been shown that silver possessing oligodynamic properties was

found in water in form of ions and in that form was affecting bacteria. If we take the concentration of silver in water to be $40\gamma/l$. Ag, then we shall have a number of ions equal to 2.4×10^{17} in 1 liter, i.e. 2.4×10^{14} silver ions in 1 ml. This number may be quite sufficient to contact with any number of bacteria usually present in water.

The first practical attempts to apply the oligodynamic properties of silver to the disinfection of water were made by Laubenheimer. They gave, however, no satisfactory results. (Note: it is very likely that the quantities of silver used were too small.)

It was only in 1928 that the method of disinfecting water by means of silver became practicable i.e. after the publication of the monograph of Dr. G. A. Krauze: "Neue Wege zur Wassersterilisierung (Katadyn)." Krauze has laid the foundations and has worked out a technical solution of the problem by constructing a series of apparatuses for the disinfection of water by means of silver. Instead of silver solutions Krauze used metallic silver (Katadynsilber) of a special porous structure which accelerated the process of dissolving the metal in water. Further Krauze prepared special filters the beds of which either contained silver shavings or had the material of which they were made coated with silver (sand, Raschig rings).

All the above mentioned devices have, however, many defects, the principal one being a gradual loss of activity, i.e. the solubility of silver diminishes because the surface of the metal becomes gradually coated with an organic film or sludge. The quantity of silver thus dissolved in water is very small and the process itself is a very slow one. The above method of disinfection may be applied only to water which contains a small quantity of organic matter.

ELECTROCATADYNIZATION

In view of the above facts endeavors were made to find new methods by which silver could be introduced into water. A new electric method, called electrocatadynization, gave a satisfactory solution of the above problem, viz.: a number of electrodes consisting of pure silver plates are connected in series with the positive and negative poles of the source of a weak direct electric current. The silver ions appearing at the anodes penetrate into the water. The number of the silver ions liberated depends directly on the strength of the electric current.

The above phenomenon is based on the First Law of Faraday. The passage of the electric current through water electrolyses the

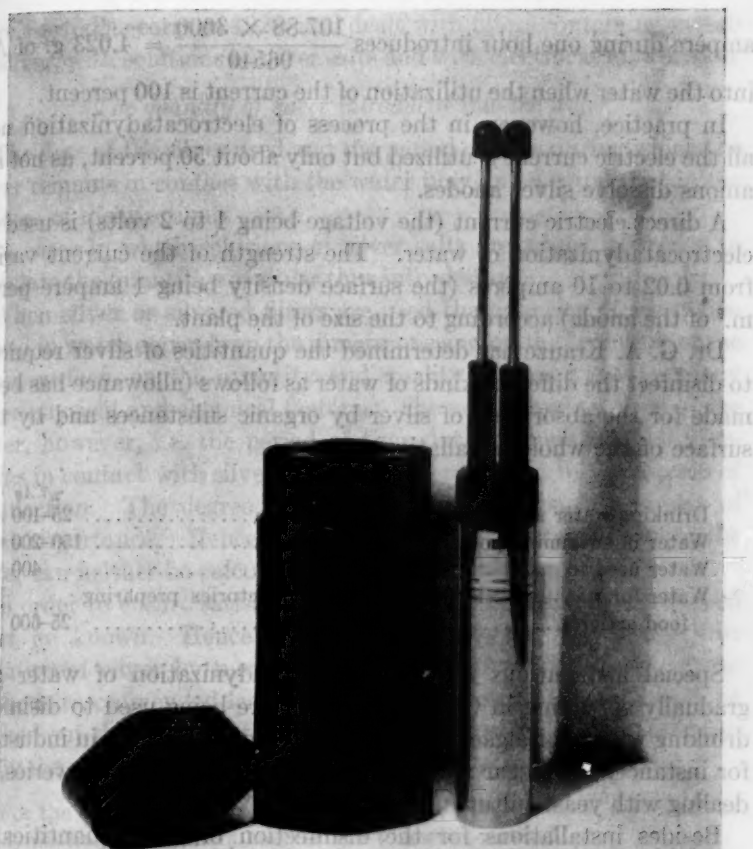


FIG. 1. Pocket apparatus for the electrocatadynization of drinking water is manufactured by the Deutsche Katadyn Gesellschaft in München. Silver electrodes are immersed in water and in this way the electric circuit is closed and the current from the battery which is placed inside the handle produces at the anode silver in quantities depending on the time of contact of the electrodes with the water. The Deutsche Katadyn Gesellschaft states that to disinfect 1 litre of water the electrodes should be immersed in water and the water stirred for 60-80 seconds. Then the water should be allowed to stand for one hour. At the end of that time all the bacteria will have been destroyed.

mineral contents of the water and some of the anions dissolve the anodes. In this way silver salts are introduced into the water in quantities proportional to the electric current. Thus a current of 1

ampère during one hour introduces $\frac{107.88 \times 3600}{96540} = 4.023$ g. of Ag into the water when the utilization of the current is 100 percent.

In practice, however, in the process of electrocatadynization not all the electric current is utilized but only about 50 percent, as not all anions dissolve silver anodes.

A direct electric current (the voltage being 1 to 2 volts) is used in electrocatadynization of water. The strength of the current varies from 0.02 to 10 ampères (the surface density being 1 ampère per 1 m.² of the anode) according to the size of the plant.

Dr. G. A. Krauze has determined the quantities of silver required to disinfect the different kinds of water as follows (allowance has been made for the absorption of silver by organic substances and by the surface of the whole installation):

	γ/l. Ag
Drinking water and mineral waters.....	25-100
Water in swimming pools.....	150-200
Water used to make artificial ice.....	400
Water for washing dishes and utensils in factories preparing food articles.....	25-600

Special installations for the electrocatadynization of water are gradually spreading in Germany. They are being used to disinfect drinking water, for algae control in swimming pools and, in industry, for instance, in vinegar and mineral water factories, in breweries, in dealing with yeast cultures, and such like.

Besides installations for the disinfection of large quantities of liquids, the Deutsche Katadyn Gesellschaft in Munich has issued a special pocket apparatus for the disinfection of small quantities of water (figure 1).

Silver which is added to water may be partially absorbed by some organic compounds, by the matter suspended in water and by the surface of the whole installation itself. Silver which has not been absorbed in the above mentioned way remains in water in the form of ions and is responsible for and preserves the germicidal property of the water.

RESULTS OF EXPERIMENTS

A series of experiments were carried out by the authors of the present paper in the laboratory of the Sanitary Engineering Department of the State School of Hygiene in Warsaw. The experiments

were started as early as 1929, and dealt with filters containing metallic silver, with solutions of silver salts and with electrocatadynization.

The quantity of silver introduced into the water

The dose of the silver used and the period of time during which the silver remains in contact with the water play an essential part in the process of disinfection.

In cases in which solutions of silver salts are added it is easy to calculate the quantities of silver thus introduced.

When silver or silvered filters are used the quantity of silver dissolved in water depends on the dimensions and on the structure of the silver surface, on the quantity and quality of water and on many other physical and chemical factors. The velocity of the flow of the water, however, i.e. the period of time during which the water remains in contact with silver, plays the essential part in the process of disinfection. The degree of purity of the silver surface is also of great importance. Hence the quantity of silver introduced into the water can neither be calculated nor even roughly estimated.

In order to ensure satisfactory disinfection, the dose of silver used must be known. Hence arises the necessity of determining the quantity of silver by means of chemical analysis. As none of the methods recommended lead to satisfactory results, the authors have worked out their own methods, which enables one to determine quite easily the presence of 2.5γ Ag in a sample of water.¹

¹ For the determination of small quantities of silver in water submitted to catadynization the authors suggest the following method.

100 ml. or more of clear or filtered water to be tested are acidulated with 2-10 drops of hydrochloric acid (1:1) and then 2 drops of potassium iodide (1:10) are added. After mixing the solution is passed through a membrane filter (porosity 1μ , diameter 2.5 cm.). The filtration is carried out with the Kolkwitz filtration apparatus for the determination of plankton. Then without removing the filter moisten it with 1-2 ml. of fresh sulphuretted hydrogen water and filter off the liquid. The colored disk thus obtained is dried in the air and compared with standards which were prepared in a similar way with standard solutions of silver corresponding to silver contents, 0, 5, 10, 15 and 20γ Ag. The above method makes it possible to determine the content of silver with an accuracy to 2.5γ Ag. Owing to easy filtration 1 liter of water may be used and the quantity of silver 0.0025 p.p.m. Ag may be determined. Greater accuracy may be obtained if a larger range of standards is prepared and membrane filters of smaller area are used.

The presence of iodine ions reduces considerably the solubility of silver iodide which is about 0.0011 p.p.m. Ag. The natural color of water, up to 40 p.p.m. plays no visible part.

TABLE 1
Influence of the mineral composition of water on the degree of utilization of the electric current

SAMPLE	KIND OF WATER	CHARACTERISTICS OF WATER							TIME OF ACTIVATION, SECONDS	ELECTRIC CURRENT, mA.	QUANTITY OF SILVER DETERMINED FROM THE STRENGTH OF THE ELECTRIC CURRENT, 7/l. Ag	QUANTITY OF SILVER DE- TERMINED ANALYTI- CALLY, 7/l. Ag	DEGREE OF UTILIZATION OF THE ELECTRIC CUR- RENT EXPRESSED IN PER CENT
		Color, mg./l. Pt.	Turbidity, mg./l. SiO ₂	Temperature, °C.	pH	Nitrates, mg./l. N	Sulphates, mg./l. SO ₄	Chlorides, mg./l. Cl					
1	Tap water	15	1	17	7.3	0.05	35	13	60	7.5	502	240	47.8
2	Tap water and salts	14	1	17	7.27	5.05	120	255	60	17.0-16.5	1,123	50	4.4
3	Tap water and salts	14	1	17	7.3	0.06	38	255	60	15.0-14.5	988	40	4.04
4	Tap water and salts	14	1	17	7.3	0.06	120	13.8	60	9.5	636	320	50.3
5	Distilled water	0	0	17	6.6	0.00	0	traces	60	0.05	3.35	traces	0
6	Distilled water and salts	0	0	17	6.8	5.00	100	250	60	14.5-13.0	921	50	5.44
7	Distilled water and salts	0	0	17	6.8	5.00	0	0	60	1.15	77	75	97.4
8	Distilled water and salts	0	0	17	6.8	0.00	100	traces	60	5.5	368	350	95.1
9	Distilled water and salts	0	0	17	6.8	0.00	0	250	60	11.5-11.0	754	25	3.31

With regard to the quantity of silver introduced into the water during the catadynization process, Dr. G. A. Krauze bases his calculations on Faraday's I-St Law, assuming that 50 percent of the electric current is being utilized. Our investigations have shown that the above method of calculating the dose of silver cannot be always applied because the mineral content of water has a decisive influence on the degree of utilization of the current used. Thus, for instance, in case of water which has a high content of chlorides (255 mg./l. Cl) 4 percent of the electric current used is utilized while in case of the same kind of water which contains 13 mg./l. Cl; the utilization of the electric current is 47.8 percent. For those reasons the use of the pocket apparatus may in many cases prove unreliable (table 1).

The influence of silver on bacteria

Our first studies on the influence of silver on bacteria were made with sand filters to which either silver shavings were added or the sand itself was silvered by chemical methods. The water to which B. Coli were added was made to pass through such filters. The reduction of the number of bacteria was up to 60 percent. This comparatively low figure may be explained by the fact that the filtering beds were rather thin and the period of time during which the water remained in contact with the filtering bed containing silver was too short, i.e. low silver content in water.

As a continuation of studies on the germicidal properties of silver as applied to the disinfection of water, a series of simultaneous experiments were made with silver salts solutions and with the electrocatadynization installations.

In order to introduce silver into water by means of an electrochemical method, a special device was constructed as shown on figure 2.

At the beginning of our experiments on electrocatadynization it was ascertained that silver thus introduced into water possessed the same properties as silver added in the form of a soluble silver salt (table 2).

The above investigations have led us to the conclusion that B. Coli added to tap water are killed within 2-3 hours when a dose of 100 γ /l. Ag is added while the same process takes 5-7 hours (with the same number of B. Coli) when the water used is obviously polluted. Observations made on the reduction of bacteria in samples of water

taken from open swimming pools, gave satisfactory results. The reduction of the total number of bacteria in water from a swimming pool was 91.5 percent in 30 minutes and 99.5 percent in 3 hours after the addition of a dose of 200 γ /l. Ag. (Agar plates, 37°, 24 hours.)

Pure water to which silver was added preserves its germicidal property a long time. For instance, on several occasions during several months bacteria were introduced into the water to which

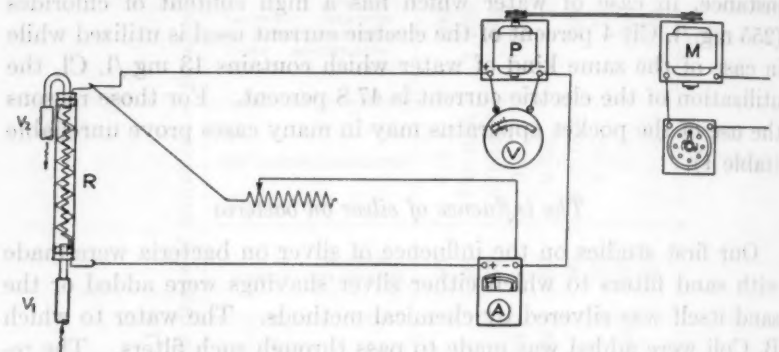


FIG. 2. The apparatus consists of a glass tube, 250 mm. long, 25 mm. in diameter, provided at both ends with rubber corks with glass tubes in them. Inside the tube are two spiral-shaped silver electrodes placed concentrically with respect to each other. The surface of each electrode is equal to 22 square cm. The ends of the two electrodes pass out from the tube and are connected with the source of a direct weak electric current viz.: the generator P driven by a small motor M. The number or revolutions of the motor may be easily changed. The current was measured with an amperemeter with an accuracy to 0.05 mA. The voltage was measured with a voltmeter with an accuracy to 0.1 volt.

During the experiment the current was regulated by means of a resistance. A current of 2.5 mA was kept up, the voltage being 1-1.2 volts. The surface density was 2.5 Amp. per 1 square meter of the anode. The above arrangement supplies 83.75 γ Ag per minute which corresponds to 50 percent of the available electric current used.

100 γ /l. Ag were added and each time it was observed that bacteria disappeared within 3-4 hours.

The influence of silver on aquatic fauna and flora

In order to study the influence of silver on organisms living in water the authors have carried out a series of experiments on the microfauna and microflora, on daphnia and on fish. The experiments show that aquatic fauna are extremely sensitive to the presence of

TABLE 2
Reduction of the number of *B. coli* in different waters after silver nitrate has been added or catadynization was performed
Figures in percent

[illegible]

A. Silver added to water in form of AgNO_3 .

B. Silver added to water by means of the experimental apparatus.

C. Silver added to water by means of the pocket apparatus.

small quantities of silver in water and comparatively small doses of that metal cause poisoning and death. Thus, for example, in samples of water rich in microorganisms when a dose of 50 γ /l. Ag was added life ceased for two weeks, in another sample where a dose of 100 γ /l. Ag was added the same was observed during a whole month and in samples to which 200 and 400 γ /l. Ag were added even at the end of 3 months no traces of life were observed.

From the above it is obvious that silver is absorbed when added to water containing organic substances. Consequently, small quantities of metal may be rendered quite harmless during a short period of time while larger quantities of silver hamper normal life for a longer period of time or destroy it altogether.

TABLE 3

The behaviour of daphnia in water which contains silver. The number of living daphnia

TIME OF OBSERVATION	DOSE OF SILVER				
	0	50 γ /l. Ag	100 γ /l. Ag	200 γ /l. Ag	400 γ /l. Ag
0	10	10	10	10	10
After 10 minutes	10	10	10	10	10
After 40 minutes	10	9	8	8	8
After 70 minutes	9	8	6	7	6
After 100 minutes	9	1	0	0	0
After 160 minutes	9	0			
After 24 hours	7				
After 48 hours	6				
After 72 hours	5				
After 96 hours	5				
After 6 days	2				

The experiments made on daphnia and the results obtained were quite interesting. It is very easy to observe the direct action of silver on daphnia. To a series of flasks containing water with some culture media and 10 daphnia each, doses of 0, 50, 100, 200 and 400 γ /l. Ag were added respectively and the behavior of the daphnia was observed. Already after the lapse of one hour the movements of the daphnia in water containing silver became different from those in the sample containing no silver. The daphnia sank to the bottom of the flask while in water containing no silver they moved about freely. At the end of 1 hour and 40 minutes all the daphnia in the flask containing silver were dead or gave faint signs of life. Daphnia in the flasks containing no silver lived several days.

The behavior of fish in water containing silver was similar. A gold fish transferred to an aquarium containing 250 γ /l. Ag after one hour showed distinct symptoms of poisoning viz.: resting on the bottom of the aquarium, secreting slime, restless breathing, and such like. At the end of 7 hours the gold fish gave no more signs of life. The experiment was repeated with another fish in water containing 50 γ /l. Ag. The result was similar, but, at the end of a fairly long time, the gold fish was transferred to water which contained no silver and was saved.

IS WATER DISINFECTED BY SILVER HARMLESS TO HEALTH?

We see from Dr. G. A. Krauze's data and from a series of other experiments that the doses of silver added to disinfect water are fairly large and seldom less than 100 γ /l. Ag. Hence arises the question whether such quantities of silver would not injuriously affect the human organism and produce symptoms of poisoning or diseases of the various organs.

The literature dealing with these problems, especially the German literature draws special attention to the disease called argyrosis. According to Poulsson 15-30 g. of Ag must be accumulated in the human body to cause argyrosis. Hence the German investigators have taken it for granted that the quantities of silver introduced into the human body with the water disinfected by means of that metal, are quite harmless for, in this way a person can consume during 70 years only as much as 6-7 g. of Ag. Similar conclusions were reached by Degkwitz and Konrich who experimented on rats and guinea-pigs. These animals were receiving 0.5 g. of Ag in drinking water per week. The experiments carried out by the authors of the present paper have led them, however, to different conclusions.

The experiments were made with several dozens of rats. They were arranged in 8 groups and each group received drinking water with a different content of silver in it. All the rats got exactly the same food and were kept in exactly the same conditions. The results of the experiments showed that all the rats which were getting 0, 50, 100, 200, 400, 700 and 1000 γ /l. Ag in their drinking water respectively appeared to be in perfectly good health. A detailed dissection of the rats showed no pathological changes. Histological examination, however, of the inner organs of those rats which were receiving their drinking water containing 400, 700 and 1000 γ /l. Ag respectively, discovered distinct pathological changes in the kidneys, liver and spleen. The larger the dose of silver the more distinct were

these changes. The results of histological examination of the spleen, liver and kidneys of rats which were receiving their drinking water containing the following doses of silver are shown below:

1. A dose of 400 γ /l. Ag: Spleen—normal. Liver—slight hyperemia. Kidney—slight hyperemia of the glomeruli, veins and capillary vessels. Small hemorrhages in the canaliculi (haematoria) causing changes of the epithelium. Accumulation of brown pigment (probably haemosyderine) in some glomeruli, in larger vessels and especially in the walls of the canaliculi in which hemorrhages took place, and in the extravasations themselves.

2. A dose of 700 γ /l. Ag: Spleen—normal. Liver—hyperemia, fresh and old tissue extravasations. Large quantities of the blood pigment in vessels and in extravasations. Kidneys—The same as in case of the dose 400 γ /l. Ag but more marked.

3. A dose of 1000 γ /l. Ag: Spleen—an increased quantity of pigment. Liver—hyperemia, tissue extravasations fresh and old. Very large quantities of blood pigment in the vessels and in the extravasations. Kidneys—as in case of dose 700 γ /l. Ag. Changes caused by hemorrhages still more marked. These facts call for some observations and reservations as to the harmfulness of water disinfected by means of silver.

The above-mentioned investigators did not carry out histological examinations; at least they make no mention of them. The dissection and general observation of rats do not authorize the drawing of general conclusions in this case. It is true that the doses of silver used in our experiments were much higher than those normally proposed for the disinfection of water which, of course, may have a certain influence and may accelerate the changes in the inner organs. In our experiments the quantities of silver introduced into the organism were, however, many times smaller than those in the experiments of Konrich and Degkwitz. It is difficult for us to decide whether observations made on rats may be extended to human beings. The decision lies with biologists and physicians. Anyhow, the results of experiments on rats make us doubt the opinion of German investigators that water disinfected by means of silver is completely harmless to the human organism. Further biological studies are required before this method of disinfecting water can be officially accepted.

SUMMARY AND CONCLUSIONS

1. Silver added to water acts in a certain definite way on bacteria and on the microfauna and microflora contained in that water.

Doses of 50 γ /l. Ag act perceptibly within a short time on such organisms as daphnia, fishes, etc.

2. The action is independent on the way in which silver is introduced into water, viz.: soluble silver salts or metallic silver which dissolves in water or by means of an electro-chemical method.

3. The larger part of the silver added to water remains ionized for a longer period of time and owing to this fact the water acquires a germicidal property. Consequently there is no aftergrowth of spore forming bacteria in water which is being kept for a long time. A secondary contamination of water with bacteria is completely removed within 3 to 4 hours.

4. The dose of silver and the time of contact necessary to disinfect water depend on the kind and chemical composition of the water.

The proposed dose of 100 γ /l. Ag for drinking water gives, in general, good results within 3 to 4 hours after the silver had been added.

5. In view of the fact that silver is precipitated on all the surfaces of the reservoir and is being absorbed by the organic and suspended matter in water, it is necessary continually to replace the quantity of silver which is being lost.

To disinfect water and to control algae in reservoirs, as in swimming pools, a dose of at least 200 γ /l. Ag is required.

6. The observation and dissection of rats fed during 100 days with water which contains 400-1000 γ /l. Ag did not show any obvious symptoms of poisoning. A histological examination, however, of the liver, kidney and spleen showed pathological changes in those organs. Constant use of water disinfected by means of silver cannot as yet be considered quite innocuous to health and this problem must be carefully examined from the biological point of view.

7. One is led to think that temporary or occasional use of water disinfected by means of silver, as during scientific expeditions, excursions or during war time will not produce symptoms of poisoning.

8. The use of silver for algae control and for the disinfection of water in swimming pools is not dangerous and may be even recommended owing to its effectiveness and absence of taste and odor which occur when chlorine is used.

9. This method of disinfecting water is much more expensive than chlorination.

10. As the mineral substances contained in water (chlorides) have a great influence on the degree of utilization of the electric current used in the electrocatadynization process, the dose of silver cannot be

based on calculations exclusively, but should be controlled by means of chemical analysis.

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AN IMPROVED ODOR TEST ON WATER

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Elimination of objectionable odors in water has received much consideration within the past several years, yet, with few exceptions, the chemical compounds causing the odors still have not been identified. This makes chemical tests for determination of the concentration of most of the odor-producing substances in water impossible, and it is necessary to rely upon odor tests to determine if such substances are present in objectionable quantities. For many years odor tests were conducted by such an unreliable method they were of little value. Certainly the method in almost universal use prior to 1933 was not accurate enough to produce even approximate results.

This inaccurate method of testing may have appealed to those who were not especially anxious to find odor in the filtered water, as may have been typical of a few of the operators of water purification plants years ago, but it is not in accord with the needs of present-day chemists who wish to report the true results regardless of whether they show the water good or bad. Confidence in the ability of the chemist who makes the odor tests is lessened if he states the tests show no odor in the water yet some of the users of the water detect objectionable odors. It is essential that we have a test sensitive enough to detect odor in lesser amounts than can be detected by the consumers in any use of the water. If we cannot tell when the water is treated to the point that odor cannot be detected by the consumers, it is likely that the water will not always be so treated. Then the public will have little pride in the quality of the water and selling palatable spring water will continue to be a profitable business in many cities.

The purpose of this paper is to comment on the sensitive odor test described in "Elimination of Taste and Odor in Water" and other publications (1) (2), calling attention to certain influencing factors,

and showing how the odor test may be used to advantage in comparing methods of eliminating or removing the odors.

EXPERIMENTS STARTED IN 1928

Shortly after starting experiments on the Lake Michigan water at Chicago to determine the cheapest and most efficient means of purifying the water, it was realized that removal of objectionable odors in the water was one of the main problems. Experiments were started in 1928 on taste and odor elimination methods. About that time water-works officials began to realize that something must be done to produce more palatable water. While treatments to remove or prevent taste and odor in water had been tried in two or three plants in America prior to 1928, with the superchlorination treatment at Toronto (3) attracting most attention, not much progress was made until 1928 and 1929. Efforts to prevent or remove objectionable tastes and odors then were started in several water purification plants, and three or four methods of eliminating tastes and odors were developed. In attempting to compare the efficiency of the several methods, the task was found to be hopeless with tests conducted in accordance with the procedure given in "Standard Methods of Water Analysis" (4).

Spaulding (5), in 1931, suggested that water containing odor be diluted with odor-free water to the point where the odor is just detectable, and later suggested (6) that the dilution be called the threshold number. This was the first suggested deviation from the procedure given in Standard Methods, which has been the procedure followed in water works practice for many years. Having made use of the dilution method for studying waste liquors from certain industrial plants in the vicinity of Chicago, the suggestion by Spaulding appeared to have merit, for it gave some measure of the concentration of odor-producing substances over that just detectable in the water. The dilution method, however, did not produce more sensitive detection of the odor, the thing most needed to improve the procedure of testing odors in water, and the consumers still could detect odor not detectable by the chemist.

SENSITIVE DETECTION OF ODOR

Realizing that detection of odors must be made more sensitive before progress could be made, considerable attention was given to improving the test. One weakness in the usual procedure which

seemed evident was that it allowed considerable dilution of the air with the surrounding air in inhaling the odor. Means of conducting

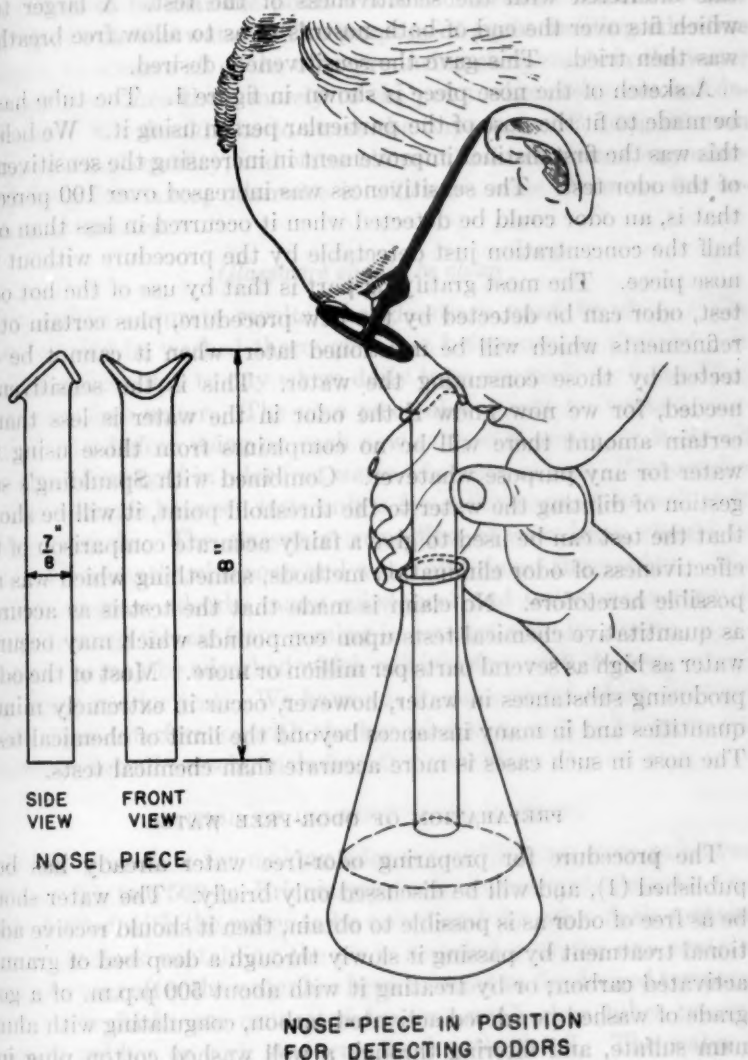


FIG. 1

the air to the nostrils without dilution were then tried. At first, tubes of various sizes with a small end which would fit into one side

of the nose were tried. This gave great improvement over the old method, although suction was required to inhale the air rapidly, and this interfered with the sensitiveness of the test. A larger tube which fits over the end of both nostrils so as to allow free breathing was then tried. This gave the sensitiveness desired.

A sketch of the nose piece is shown in figure 1. The tube has to be made to fit the nose of the particular person using it. We believe this was the first distinct improvement in increasing the sensitiveness of the odor test. The sensitiveness was increased over 100 percent; that is, an odor could be detected when it occurred in less than one-half the concentration just detectable by the procedure without the nose piece. The most gratifying part is that by use of the hot odor test, odor can be detected by the new procedure, plus certain other refinements which will be mentioned later, when it cannot be detected by those consuming the water. This is the sensitiveness needed, for we now know if the odor in the water is less than a certain amount there will be no complaints from those using the water for any purpose whatever. Combined with Spaulding's suggestion of diluting the water to the threshold point, it will be shown that the test can be used to give a fairly accurate comparison of the effectiveness of odor elimination methods, something which was not possible heretofore. No claim is made that the test is as accurate as quantitative chemical tests upon compounds which may occur in water as high as several parts per million or more. Most of the odor-producing substances in water, however, occur in extremely minute quantities and in many instances beyond the limit of chemical tests. The nose in such cases is more accurate than chemical tests.

PREPARATION OF ODOR-FREE WATER

The procedure for preparing odor-free water already has been published (1), and will be discussed only briefly. The water should be as free of odor as is possible to obtain, then it should receive additional treatment by passing it slowly through a deep bed of granular activated carbon; or by treating it with about 500 p.p.m. of a good grade of washed powdered activated carbon, coagulating with aluminum sulfate, and filtering through a well washed cotton plug in a funnel. Water from a granular activated carbon unit in which the odor is reduced to where it is not detectable, or just detectable, is used for the source of our dilution water. This water, before use, is passed through another bed of granular activated carbon about four

feet deep. The carbon in the deep bed is changed every two or three months and long before it has adsorbed enough of the odor-producing substances to be near the point where a detectable amount of odor will be left in the water. The purpose of again treating odor-free water is to remove all of the odor-producing compounds in the water and not to reduce them merely to the point where they are not detectable. We should like to stress the importance of using dilution water of a high quality, and water almost absolutely free of any odor-producing substance, otherwise it will have some effect on the accuracy of the test.

Glassware should be clean

To obtain accurate results, the glassware must be clean. The flasks should be washed thoroughly just before use, or they may be held over from day to day where daily tests are made by being filled with odor-free water. The nose piece also should be washed thoroughly just before using on each new sample of water, or it should be kept submerged in odor-free water when not in use. This applies to the intervals between tests only a few minutes apart as well as to longer periods. The glassware, regardless of how kept, should be washed frequently with soap and water and rinsed thoroughly. The surface of glass adsorbs many substances and unless precaution is taken to keep the air from coming in contact with its surface, some substances may be adsorbed which will interfere with the test, especially the hot odor test. We have not found a metal which does not cause some interference with the hot odor test, so it is better to use glassware for all vessels, including the nose piece.

METHOD OF CONDUCTING ODOR TESTS

In the procedure for making odor tests which has been published already (1), two 500-cc. Erlenmeyer flasks were recommended. One flask is filled with the water to be tested and the other flask contains air. The flask containing the air is inverted over the one containing the water after the water has been brought to the desired temperature. The flasks are connected by two small glass tubes passing through rubber or cork stoppers, lined with tinfoil. The water is then distributed about one-half in each flask and shaken thoroughly. All of the water is then collected in one of the flasks and the air in the other. This gives 500 cc. of air for inhaling. Use of two flasks made considerable labor for routine work, and the procedure now

being followed for routine work is to use one 500-cc. flask, filling it one-half full of water and covering with a watch glass. It is difficult to prevent tinfoil giving off some odor in the hot odor test. By use of one flask there is slightly more than 250 cc. of air for breathing, which seems to be sufficient.

To make the cold odor test, one 500-cc. Erlenmeyer flask is filled one-half full with a portion of the sample, the flask covered with a watch glass, the temperature brought to between 20° and 25°C., and the cold odor test made. Before making the test, the water in the flask is shaken vigorously for two or three seconds, then the nose piece is inserted and the air inhaled. The intensity of the odor and the kind are recorded, following the procedure given in Standard Methods of Water Analysis. An intensity of 1 means the odor is very faint; 2, that it is faint; 3, that it is distinct; and 4, that it is decided. The kind of odor is recorded grassy, fishy, musty, chlorophenol, etc. From this test the odor threshold is predicted. Assume the prediction is 5, which means that the odor is just detectable when one volume of the water is added to 4 volumes of odor-free water. Fill five 500-cc. flasks one-half full of water containing dilutions of 1 to 2.5, 1 to 3, 1 to 4, 1 to 5, and 1 to 7. These portions are tested in the same manner as the portion without dilution, starting with the greatest dilution and testing in the order of decreasing dilution. If the odor is just detectable in the 1 to 4 dilution, greater dilutions will have no detectable odor and lesser dilutions will have an increasing amount of odor, although none of the dilutions may have an odor intensity which should be recorded 2. Unless there is at least one dilution which has no detectable odor, greater dilutions should be made. At least two of the dilutions should contain odor which is detectable.

Hot odor tests are made in the same general manner, except the water is heated to a temperature of approximately 70°C. before making the test. The hot threshold number usually will be from 3 to 8 times the cold odor threshold. Assume the predicted threshold is 20; prepare dilutions of 1 to 11, 1 to 15, 1 to 19, 1 to 24, and 1 to 29. If the odor is just detectable in the 1 to 15 dilution, the threshold is 16.

Threshold number

One hundred divided by the percent of the sample in the diluted portion in which the odor is just detectable gives the threshold

number. Assume the dilution is 1 to 4, the sample contains 20 percent of the original sample and 80 percent of odor-free water. One hundred divided by 20 gives 5, the threshold number.

Air dilution method

Instead of diluting the water with odor-free water for determining the threshold point, Fair (7) has developed a method of diluting the air. The theory of the gas-water equilibrium indicates the air-dilution method is sound, providing the dilutions can be made quickly and accurately. Fair and Wells (8) developed an air proportioning device, called an osmoscope, which can be set for dilutions varying in a geometric ratio of 2 to 1, or 100 percent. Close results cannot be obtained with a device giving this ratio. Accurately proportioning hot air is not easy, and we do not believe the instrument developed by these authors will give the most accurate results. Several defects may be pointed out in the instrument illustrated, but space will not be taken to discuss the defects. Perhaps some of the defects already have been corrected, but there are others which we do not believe possible to correct.

GAS-WATER EQUILIBRIUM

The gas-liquid equilibrium laws

To explain more fully the importance of using some uniform procedure for making odor tests, it is believed advisable to discuss briefly the equilibriums which exist in a mixture of gases each exerting its pressure independently of the others. Expressed in other words, each gas contributes a pressure in proportion to the volume it occupies in the mixture. For example, if the total pressure of a mixture of gases is 760 mm. of mercury (one atmosphere), a certain gas occupying one-fourth of the total volume of the mixture will have a pressure of one-fourth of the total pressure, or 190 mm. This is called the partial pressure of the gas.

According to Henry's law, the solubility of a gas at a given temperature is proportional to the pressure of the gas above the solution. Therefore, air, in which 10 percent of its volume is some other gaseous substance such as hydrogen gas, will be at equilibrium with water containing 10 percent as much dissolved hydrogen gas as it would contain if the water was exposed to pure hydrogen gas. Some gases do not follow these laws exactly, yet the deviations usually are not great. With these facts in mind, it is easy to see that water at

a definite temperature which contains some amount of a dissolved gaseous compound, when brought to equilibrium with the gaseous phase of some other gaseous substance such as air, will give up approximately one-half of this dissolved compound when the total volume of the air plus the gaseous compound released from the water is equivalent to the maximum solubility (in volume of gas) of the dissolved compound. This is assuming that the temperature remains constant.

To illustrate: The solubility coefficient of carbon dioxide in water at 0°C . is 1.713, or 1,713 cc. of carbon dioxide in one liter of water. Assume one liter of water which contains 100 cc. of carbon dioxide is brought in contact with about 1,663 cc. of CO_2 -free air and agitated until equilibrium is established. About 50 cc. of the carbon dioxide will leave the water and mix with the air above the water to form about 1,713 cc. of gas, and about 50 cc. of the carbon dioxide will be left in the water. This is equivalent to 29.2 cc. of carbon dioxide per liter of air, or 2.92 percent of the volume, or a partial pressure of 2.92 percent of the total gas pressure. Fifty cubic centimeters of dissolved carbon dioxide in water is 2.92 percent saturation at 0°C ., the same percent as the concentration in the air above the water. Perhaps the results will not be exactly as stated, for carbon dioxide may not follow exactly the Henry law for water-gas equilibrium.

The solubility coefficient of oxygen in pure water at 0°C . is 0.04889, or 48.89 cc. of oxygen per liter of water. Assume that it is desired to reduce by one-half the dissolved oxygen in water which contains 8 cc. of oxygen, by bringing it to equilibrium with nitrogen gas. There must be 4 cc. of the oxygen removed from the water and mixed with the gas above the water. The total volume of gas above the water after equilibrium has been established will be about 48.89 cc. for 4 cc. of oxygen to remain dissolved in the water; that is, the volume of gas at equilibrium must be the same as the solubility of oxygen when the water is exposed to pure oxygen gas. The solubility of oxygen at 20°C . is 31.02 cc. per liter. With 8 cc. of dissolved oxygen, equilibrium will be established at one-half oxygen reduction when the 4 cc. of gaseous oxygen removed from the water is mixed with 27 cc. of nitrogen gas to form a total of 31 cc. of gas above the liquid.

Effect of temperature on vapor pressure

Substances which exist as a liquid at the water temperature are dissolved liquids, that is, they most likely would be in the dissolved

state to be present in the water of a public supply, though it may be possible under some conditions to have oil globules in water. The amount of vapor which will be given off depends on the vapor pressure of the compound at the temperature, and the proportion of the substance in the water. Raoult's law states that in case more than one constituent of the solution is volatile, each one has a partial pressure in the vapor over the solution.

The vapor pressure of water at 20°C. is 17.36 mm. of mercury. At 70° the vapor pressure of water is 233.3 mm. of mercury, or about 13.4 times as great. There is considerable variation in the ratio of vapor pressure at 20° and at 70° for substances having boiling temperatures less than about 150°, and while the ratio may not average 13.4 it probably will exceed 10. This means for the average compound there probable will be more than 10 times as much of the substance in the gaseous state at 70° as there will be at 20°. This also may hold for compounds having a very high boiling point, though we lack specific information.

Should compounds which are in the liquid state at temperatures ordinarily used in making odor tests follow the general rule for gases, the amount of such compounds removed by aeration with an equal volume of water and air is not much. Very likely some compounds with high boiling points deviate greatly from the general rule for gases, yet considerably more of the vapor is given off at the higher temperature. Perhaps it is not well to predict too much on what will happen with extremely minute quantities of a substance in water on the basis of what happens with much higher concentrations, however, the tendency should be in the direction of the characteristics found at higher concentrations.

Reduction of dissolved compounds by aeration

If the general laws for true gases were applicable to all odor-producing substances, it would not be difficult to compute approximately the amount of the compound which will be removed from a given volume of water when brought to equilibrium with a definite volume of air which contains none of the dissolved compound.

$$V = \frac{B - C}{P}, \text{ or } V = \frac{A(B - C)}{C}, \text{ or } C = \frac{AB}{V + A}$$

A = Cubic centimeters of the gaseous compound which will be dissolved in one liter of water when the water is at equilibrium with the pure gas. For example, the maximum

volume of oxygen dissolved in the water when exposed to pure oxygen gas.

B = Cubic centimeters of the gaseous substance which is dissolved in one liter of water to be tested.

C = Cubic centimeters of the gaseous compound remaining dissolved in one liter of water after equilibrium has been established by agitating the water with some definite volume of another gas such as air.

V = Volume in cc. of all gaseous compounds (air plus dissolved substance released from the water) above the solution after equilibrium has been established.

P = The volume of the gaseous compound in the air, or other gas to which the water is brought in contact with, divided by the total volume of the mixed gases. $P = (B - C)$ divided by V , or $P = C$ divided by A .

This equation is not intended to apply to compounds having a boiling point higher than that of the temperature of the water at which the test is made, for the water cannot be exposed to the pure gas at atmospheric pressure. Probably an equation involving the vapor pressure of the compound could be made applicable to compounds with high boiling points.

The equation does not tell the solubility of the product in water, and at the present time the solubility and boiling points of most of the substances producing odors in water are not known. Therefore we are no nearer a quantitative test than before. The equation does show, however, that the volume of the odor-producing gas leaving the water to go into the air when the water is agitated with air, as is done in the odor test, is quite variable. The ratio of the volume of air to water in the flask for highly soluble compounds is not of as great importance as it is for slightly soluble compounds.

Perhaps too much space has been given to the gas-water equilibria, but the importance which soon will be placed upon the odor test justifies an extended discussion of the various factors which influence the test. The equation which has been given may be of more value in aeration than in odor testing, especially when more of the compounds requiring removal from water have been identified. Transferring part of the odor-producing substance from the water to the air so it can be inhaled is an aerating process.

IMPORTANCE OF KEEPING THE AIR-WATER RATIO CONSTANT

In the procedure for conducting odor tests which is recommended, the air-water ratio is approximately 1, that is, an equal volume of air to that of water. The importance of this is evident from what has just been said. Again taking carbon dioxide for illustration, the concentration in the water before it is brought in contact with an equal volume of air free from CO_2 is approximately 1.7 times the concentration at equilibrium. This is assuming that it follows the gas laws, which probably is not exactly true. Should the procedure for making odor determinations given in the 1933 edition of Standard Methods of Water Analysis be followed (the odor determination procedure has been revised in new edition), in which 150 cc. of water are added to a 500-cc. flask, the percentage of CO_2 in the air above the water at equilibrium is considerably less than it would be if equal volumes of air and water are used.

The average 500-cc. Erlenmeyer flask holds about 530 cc. when covered with a watch glass. This gives an air-water ratio of about 2.5 for 150 cc. of water. When it is compared with tests using equal volumes of air and water the concentration varies widely, but for some of the odor compounds it may be not more than 50 percent of that which will be in the air where equal volumes are used. Table 1 gives the results of a typical odor threshold determination in which the air-water ratio was varied. The last column in table 1 gives computed values which do not vary greatly from the actual results. The difference in the 2.5 air-water ratio and the equal volume ratio in this case is about 33 percent. A , in the equation, was assumed to be 2,000 merely because this value gives points which fit closely the points determined by tests. B , which can be any value less than A , corresponds to the odor threshold when the air-water ratio is zero. B may be determined by chemical tests when the compound producing the odor is known and methods of determining it quantitatively are known. It, of course, is not practical to determine B by the odor test, for some appreciable amount of air is necessary for inhaling.

By increasing the amount of water used in the hot odor test over that customarily used, the sensitiveness of the test has been increased considerably. The odor threshold probably will not vary exactly as indicated by the equation, due to the presence of mixtures of compounds varying in solubility and vapor pressure. Each compound may have a different value for A .

The effect of the air-water ratio suggests the desirability of using a larger volume of water than that of air. Fully 250 cc. of air should be available for inhaling, so an increase in the volume of water over that recommended in the test would necessitate the use of larger flasks. Larger flasks would make it desirable to use larger water baths for heating, and also a longer time of heating will be required. In addition to this, more dilution water would be required. For routine odor determinations 500-cc. flasks filled one-half with water probably is the best size flask to use. Larger flasks and larger amounts of water can be used where great accuracy is desired.

TABLE 1
Effect of the air-water ratio on hot odor threshold number
Tests made on Lake Michigan water

VOLUME OF WATER	VOLUME OF AIR	RATIO OF VOLUME OF AIR TO VOLUME OF WATER	HOT ODOR THRESHOLD NUMBER (DETERMINED BY TEST)	COMPUTED THRESHOLD NUMBER (A = 2,000; B = 0.1)
cc.	cc.			
900	200	0.22	60	54
800	300	0.38	50	51
700	400	0.57	50	47
600	500	0.83	40	42
500	600	1.20	30	38
400	700	1.75	30	32
300	800	2.67	25	26
200	900	4.5	25	19
100	1,000	10.0	12	10
50	1,050	21.0	8	5
25	1,075	43.0	5	3

COVER FOR FLASKS

Watch glasses are used most extensively for flask covers. It is realized that this is a source of error, especially in the hot odor test. The watch glasses do not fit tightly, and there is some leakage of the warm air from the flask. A water bath heated to about 80°C. requires several minutes for the water inside of the flasks to reach a temperature of 70°. But as the water is not agitated during the heating period, the escape of the odor-producing substances through leaks in the cover glasses may not be great. The water should be heated as promptly as is practical, and the odor test should be made promptly after the water reaches the desired temperature. Thorough agitation should be given the water to establish approximate

equilibrium of the dissolved gases and the concentration of these gases in the air within the flask, yet too long a period of agitation will cause some dilution of the inside air due to loosely fitting cover glass. Thus it is seen that loosely fitting cover glasses as is now commonly used may be the source of considerable error in odor determinations in the hands of the careless worker. Perhaps a tight-fitting cover glass can be devised, and this is a matter which should receive consideration.

REPEATED TESTS ON SAME PORTION OF WATER NOT ADVISABLE

A common habit in odor testing is to shake the flask, inhale the air, and then shake again and inhale as a check on the first impression of the odor present. To determine the error that might be introduced in this manner, a sample of water having a hot odor threshold of 16, using equal portions of water and air, was heated to 70°C. in a two-liter flask. It was agitated thoroughly in accordance with the usual procedure, then the air was replaced with fresh air. The odor threshold was determined on one-half of this water, and was found to be 10. The threshold was reduced about 37.5 percent by shaking with an equal volume of air. The other one-half was again heated in a one-liter flask to 70°C., agitated, and the air replaced with fresh air. The threshold was then determined in the usual manner, and was found to be 6. This was a total reduction from the original sample of about 62.5 percent. Such tests are mentioned to stress the importance of care in making the odor test, and the importance of using a definite procedure.

ACCURACY OF THE ODOR TEST

There is difference of opinion as to the accuracy of the odor test. Fair (7) states that it is doubtful whether we should attempt to measure and express, in routine water analysis, threshold differences less than 100 percent, or odor concentrations differing by less than 2 to 1, basing this, so he states, upon his own work as well as that of Allison and Katz (8). According to Henning (9), Hermanides detected threshold differences varying 24 to 62 percent for different compounds. Fair further states that the differences calculated from the data of Allison and Katz are not the minimum detectable differences in odor but differences in intensity that are recognized without resorting to great refinement. Allison and Katz, of course, were not attempting to determine minimum recognizable differences in

odor intensity, but were using a scale of expression for the range of odor concentration tried, dividing it into 5 expressions. To conclude that we should not attempt to determine and express threshold differences less than 100 per cent from Allison and Katz's data, which happen to vary approximately in a certain geometric ratio of the concentration of the substance in the air, does not seem justified.

We find that differences of 20 percent in the odor threshold are recognizable by the skilled worker when the improved method of odor testing is used. Some claim they can detect a 10 percent difference, although we admit this seems too close. The statement that a 20 percent difference is recognizable at the threshold point is based upon our own work, and the differences which certain visitors to our laboratory have been able to detect when samples are prepared without their knowledge of the dilution. We feel certain that skilled workers will have no difficulty in recognizing differences much closer than 100 percent. It will be shown that unless the accuracy is closer the test is not of much value in comparing odor elimination methods.

EXPRESSION OF RESULTS

A scale of dilutions of the sample with odor-free water, which is believed to be satisfactory for accurate work, is: 1 to 0.25, 1 to 0.5, 1 to 0.75, 1 to 1, 1 to 1.5, 1 to 2, 1 to 2.5, 1 to 3, 1 to 4, 1 to 5, 1 to 7, 1 to 9, 1 to 11, 1 to 15, 1 to 19, 1 to 24, 1 to 29, and so on, making the next higher dilution not more than about 25 per cent greater each time. The results may be expressed as the dilution number or dilution factor, such as: 1, 1.25, 1.5, 1.75, 2, 2.5, 3, 3.5, 4, 5, 6, 8, 10, 12, 16, 20, 25, 30, 35, 40, etc. The dilution number or factor is the figure by which 100 is divided to give the percent of the original sample in the diluted portion. The largest number in which odor is detectable is the threshold number. This is shown in tables 2 and 3. Threshold number of 0 means that no odor is detectable, and threshold number of 1 means that the odor is not detectable in the dilution of 1.25, but is detectable without dilution. Threshold of 1.25 means that the odor is detectable at this dilution, but not detectable upon further dilution. In odor determinations, the column for recording the dilution number or factor can be headed "dilution," if it is desirable to shorten the heading.

In making odor tests on a certain sample of water it is evident that all of the dilutions suggested, up to the threshold point, should not

be made. The scale is given to show the various dilutions which should be made next above and below the threshold point. As previously stated, at least one portion tested should have no odor and at least two portions should contain odor. Should the threshold number be 8, there should be tested and recorded results on dilutions of 6 and 10 as well as the dilution of 8; or if the threshold is 2, there should be recorded tests on dilutions of 1.75, 2, and 2.5. The sample always should be tested for odor intensity without dilution, and also for recording the kind of odor. The information on the sample

TABLE 2
Typical odor threshold tests
September 24, 1935

DILUTION NUMBER	COLD ODOR 20° TO 25°	HOT ODOR 65° TO 70°
1	2 gf	4 gf
2	1 g	3 gf
3	1 g	2 gf
4	1 g	2 gf
5	1 g	2 gf
6	1 g	2 gf
8	0	1 gf
10	0	1 gf
12		1 g
16		1 g
20		1 g
30		1 g
40		0
Threshold number	6	30

g = grassy; f = fishy. 0 = no odor; 1 = very faint; 2 = faint; 3 = distinct; 4 = decided.

is made more complete by testing several intermediate dilutions such as are given in tables 2 and 3. These intermediate dilutions are not essential for getting the threshold number, but they give a clearer picture of what happens as the odor is reduced by diluting the water with odor-free water.

The pO scale not recommended

Fair (7) suggested a pO scale of expressing odors in which the index number of the odor is the logarithm of the odor threshold to

the base 2. pO of 0 (2^0) is threshold of 1, that is, an odor just detectable but not detectable upon dilution of the sample with odor-free water, or dilution of the air containing the odor. pO of 1 (2^1) is threshold of 2, pO of 2 (2^2) is threshold of 4, pO of 3 (2^3) is threshold of 8, pO of 4 (2^4) is threshold of 16, and so on. The scale has no expression for water in which no odor is detectable, for the starting point (pO of 0) is when there is a detectable amount of odor, which represents some concentration of the odor-producing substance. Fair, as has been stated, justified this scale partly upon the work of Allison and Katz, in which odors of gases of definite concentrations in the air were determined.

The determinations by Allison and Katz were made by smelling the gases as they escaped from a glass funnel held over the nose. There is no assurance that this did not allow dilution of the gases with the surrounding air. These authors expressed the results as detectable, faint, noticeable, strong and very strong. Fair found that Allison and Katz's results, when plotted on paper having a geometric (logarithmic) scale for odor concentration and an arithmetic scale for intensity of sensation, gives a straight-line tendency with a concentration difference of about 100 percent for each expressed difference in intensity. In other words, the concentration of odor-producing compound when the odor was recorded as faint was about twice that when it was recorded as detectable, and the concentration when recorded noticeable was about twice that when it was recorded as faint.

The pO scale not suitable for our work

There is danger in taking the results obtained in one line of work and applying them in another line. We find upon examination of odor threshold tests on more than 2,000 samples of water in which the intensity was recorded in accordance with that given in Standard Methods of Water Analysis (No odor, very faint, faint, distinct, decided, very strong), that the results do not correspond with Fair's pO scale. These tests were made with no thought as to whether they did or did not follow some definite scale. They show that when the odor was recorded as "faint" the threshold averaged about 3, when it was recorded "distinct" the threshold averaged close to 9, and when it was recorded "decided" the threshold usually was in excess of 30. This applies to odor determinations made by the improved method. Looking over a few odor threshold tests made

without the nose piece, prior to its development, the differences are roughly 100 percent and might be somewhere near the pO scale.

Adoption of a scale should await more careful work

Recognizable differences in odor sensation are so variable, depending on the manner in which the test is conducted, it should be evident that an accurate scale cannot be given at the present time. Certainly the suggested scale does not apply to our work, and while others may record the intensity of the odor differently and give results which are closer to the suggested scale, it is believed their results will not conform to it if the tests are made by the most sensitive method of detecting odors. Had Allison and Katz used a method of conveying the gases directly to their nostrils without possibility of dilution with the surrounding air, their ratios may have been different. Also their conception of what is faint, noticeable, etc., in their line of work may not mean the same as such expressions used by the water works chemists. Should there be some reason for adoption of a geometric scale, it should await general use of the sensitive method of detecting odors so that the scale will have a more definite meaning.

Results expressed in threshold number most suitable for activated carbon treatment

Activated carbon in the powdered form is the most extensively used substance for removing taste and odor in water. We find from a large number of tests that for a given odor the amount of powdered carbon required to reduce the odor to a certain threshold is in proportion to the threshold. To illustrate, if the water before treatment has a hot odor threshold of 20, and it is desirable to reduce the threshold to 2, a certain amount of powdered activated carbon will be required which we will assume to be 18 p.p.m. This is 1.0 p.p.m. of the powdered carbon per threshold reduction. Should the odor in the water increase to a threshold of 30, about 28 p.p.m. of carbon will be required to reduce the threshold to 2, unless there is a change in the type of odor requiring some other ratio. If there is a reduction in the odor to a threshold of 12, about 10 p.p.m. of the powdered carbon will be required.

We are well aware that the parts per million of powdered carbon required per threshold reduction varies greatly in different plants due to different substances producing the odor, and in the same plant

where there is change in the substance causing the odor. Notwithstanding these limitations, the operators of water treatment plants will find it helpful to determine the relation between odor threshold reduction and amount of carbon used. In so doing, the minimum amount of powdered carbon necessary to produce the desired odor reduction can be computed very accurately when there are changes in the concentration of the odor in the water. If the results were recorded according to some geometric scale, it would be necessary to convert the results to threshold numbers to use them advantageously. Also we would be at considerable disadvantage in jumping from say threshold of 8 to 16, or from 16 to 32, if Fair's suggestion of making determinations varying 100 per cent is followed. Certainly this wide variation is not close enough for use as a guide in the application of odor removal treatments. For plants using odor removal treatments it is much better to record the results in threshold numbers, and to vary the dilutions in accordance with the scale recommended. Then if it is found desirable to think of the results in terms of some geometric ratio, it is not difficult to so do. Little effort would be required to think of our results in terms of a threshold of 3 meaning the odor is faint, a threshold of 9 meaning the odor is distinct, and a threshold of 30 meaning the odor is decided.

COMPARING ODOR ELIMINATION METHODS

The tests which will be given to illustrate the method of comparing odor elimination methods must not be construed as being exact comparison of the treatments. They are given to show the method and not the superiority of one treatment over another, for these same treatments conducted in the same manner may not have the same relation on some other water. They are correct for the particular water in the particular manner in which they were conducted. Some of the treatments may not have been used in the most effective manner.

Tests were made on Lake Michigan water without any treatment; the water coagulated and filtered; the water treated with activated carbon, coagulated, and filtered; the raw water treated with ozone; superchlorination; coagulation, superchlorination, and filtration; the ammonia-chlorine treatment; and aeration. All of the experiments were laboratory experiments, except the coagulation, superchlorination and filtration experiments where filters 6 and 7 were used. The superchlorinated water was dechlorinated before testing. The

TABLE 3
Comparison of odor elimination methods on Lake Michigan water
Odor tests, September 18, 1935

DILUTION FACTOR	RAW WATER	COAGULATED AND FILTERED	ACTIVATED CARBON, P.P.M.				OZONE		CHLORAMINE			SUPERCHLORINATION, P.P.M.				AERATION*			
			3.0	6.0	9.0	12.0	15.0	After 30 Min.	After 3 Hours	Cl 0.2	Cl 0.4	Cl 0.6	1.0	3.5	6.0	Filter 6	Filter 7	Coarse Spray	Fine Spray
70°C.																			
1	3 g	3 g	3 g	2 g	1 g	0	3 z	3 z	3 g	3 g	3 g	3 g	3 g	2 g	3 g	3 g	3 g	3 g	
2	2 g	2 g	2 g	2 g	1 g	0	2 z	2 z	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	
3	2 g	2 g	2 g	1 g	0	0	2 z	2 z	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	
4	2 g	2 g	2 g	1 g	0	0	2 z	2 z	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	
5	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
6	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
8	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
10	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
12	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
16	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
20	1 g	1 g	1 g	1 g	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Threshold	16	12	8	5	3	1	0	12	8	16	12	16	16	12	20	12	10	16	12
20°C.																			
1	2 g	2 g	1 g	1 g	1 g	0	0	2 z	2 z	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g	2 g
2	1 g	1 g	1 g	0	0	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g
3	1 g	1 g	1 g	0	0	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g
4	1 g	1 g	1 g	0	0	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g
5	0	0	0	0	0	0	0	1 z	1 z	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g	1 g
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Threshold	4	4	3	2	1	0	0	5	4	4	4	4	4	3	4	3	3	4	4

g = grassy; e = earthy; z = ozone; c = chlorinous; v = vegetable; f = fishy.

* Note: Raw water threshold was 20 at the time the aeration tests were made.

experiments were conducted on the same day and as near the same time as was possible, but all could not be conducted at once. Where there was a lapse of an hour or more between collecting samples for testing, additional raw water samples were collected. In a few instances there was some change in the raw water, though not very much.

Table 3 gives the results of a typical set of comparison experiments. A number of such comparisons have been made. To obtain close comparison of the effectiveness of the treatments as conducted, it is evident there must be close measurement of the odor thresholds. The task would have been almost hopeless by use of the pO scale in the manner suggested. At least the results would not have been close enough for a very good comparison.

SUMMARY

A sensitive odor test for water is described. The improved method is capable of detecting odor in water when it occurs in concentrations less than one-half that which was detectable heretofore.

Odor in water can now be detected in quantities less than can be detected by the users of the water.

The air, after agitation with the water in a flask, is conveyed to the nostrils through a glass nose piece to prevent dilution with the surrounding air.

The procedure for conducting odor tests in which the water is diluted with odor-free water to the point where the odor is just detectable is described. The dilution where the odor is just detectable is called the threshold number.

The ratio of air volume to water volume in the flask materially affects the results. An equal volume of air and water in a 500-cc. Erlenmeyer flask is recommended for routine odor determinations. A means of computing the effect of varying the air-water ratio is given.

Increasing the volume of water over that used heretofore in the hot odor test has increased the sensitiveness of the test considerably.

Loose fitting covers for the flasks allow some of the odor to escape from the flask before testing and is a possible source of error.

Repeated tests on the same sample of water gives erroneous results, for the odor is lessened each time the water is agitated with the air and the air is replaced with fresh air.

Odor threshold differences of 20 percent are easily detected by skilled laboratory workers.

The pO scale of recording odor tests suggested by Fair is not the most convenient form of expressing the results. It does not conform to results determined by the most sensitive method of detecting odors, and it cannot be used for computing dosages of powdered activated carbon. Variations in odor sensation, based upon a large number of tests, do not conform to the suggested pO scale.

The osmoscope as now manufactured gives dilutions which vary too widely for close results.

Tests showing how odor threshold determinations may be used for comparing various odor removal treatments are given. The efficiency of various treatments for removing a particular odor may be compared fairly accurately by determining the odor threshold numbers of the water before and after treatment.

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SUSPENDED SOLIDS IN THE FOAMING AND PRIMING OF BOILER WATER

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Until 1927 no one seems to have questioned the belief that finely divided solid matter in a boiler water greatly increases the carry-over of liquid water into the steam. In that year Joseph and Hancock, two British chemists, published a paper (1) containing quantitative results both with an experimental boiler and with a locomotive boiler. These results showed that under the conditions of the experiments the various kinds of solid matter employed had little or no effect on the priming.¹ In the summary at the end of the paper is this sentence, "The effect on priming of finely divided calcium carbonate or boiler scale is negligible."

This statement was not readily accepted in this country and so far as the author is aware, is not now accepted by the majority of engineers. Slowly accumulating quantitative research on the subject, however, tends in part at least to confirm Joseph and Hancock's conclusion, and it is worthwhile then to examine both sides of the question.

EVIDENCE THAT SOLID MATTER PROMOTES PRIMING

First, what is the evidence for the belief that solid matter promotes priming? There is plenty of it. The experience of ore flotation shows that finely divided solids stabilize foams, and books on colloid chemistry state it as an experimental fact. Bancroft (2) explains the effect by saying that the solids "armor plate" the foam bubbles. Boiler water chemists, however, offer even more direct evidence in favor of this side of the case. The author (3) published a paper in 1924 in which a long list of experiments is recorded showing the stabilizing effects of finely divided solid matter on the foaming of such salt solutions as appear in steam boilers. These experiments

¹ The word priming as used in this paper means any carry-over of liquid water in the steam.

were all made in glass vessels at atmospheric pressure, but it was assumed at that time that the same effects would occur in boilers. In 1929 Eberle (4) who worked with an experimental boiler stated that suspended solids had more effect than dissolved salts in producing wet steam.

Finally, there is presumptive evidence that in the early days of steam engineering when boiler pressures were low, suspended solids played a more important rôle than at present in the production of wet steam. Reference will again be made to this point.

In brief, anyone who had read the literature of boiler water chemistry prior to and closely following the appearance of Joseph and Hancock's paper, could have come to only one conclusion, namely, that suspended solids greatly promote wet steam.

EVIDENCE THAT SOLID MATTER DOES NOT PROMOTE PRIMING

Let us turn now to the evidence for the other side of the case. Joseph and Hancock experimented with a cylindrical boiler having a working capacity of 25 liters (6.6 U. S. gallons), which they operated at 150 to 155 pounds pressure. The priming of various salt solutions was first determined and then the priming of the solutions of the same salts at the same concentrations but with solid matter added. The added solids were in some experiments finely divided calcium carbonate and in others powdered boiler scale (carbonate and sulfate). In brief, the concentrations of dissolved and suspended matter were measured and were varied independently of each other. In one experiment the solids were produced inside the boiler by pumping calcium chloride solution into sodium carbonate solution in the boiler and thereby precipitating calcium carbonate. This latter experiment showed a little effect, but in the main the investigation amply bore out the statement quoted above, "The effect on priming of finely divided calcium carbonate or boiler scale is negligible."

Joseph and Hancock also made an experiment with a locomotive boiler, which they report as follows: "Trials with an unsoftened well water (dissolved solids = 800 p.p.m; total hardness = 30°) and with the same water softened to 3° showed that priming commenced in each case at practically the same concentration of dissolved solids; i.e., about 3200 p.p.m." There was, of course, a far heavier precipitation in the boiler when fed with the unsoftened water than was the case when the softened water was used.

In 1930 Hancock (5) repeated many of the experiments made in

the previous investigation with Joseph and obtained the same results.

The question was of such importance that the author and one of his students, S. F. Whirl (6) built a boiler at Ohio State as nearly as possible like the one used by Joseph and Hancock and carried out an extensive series of experiments with salt solutions and added solids. Powdered limestone and ground flint were used. The results were the same as those obtained by Joseph and Hancock, when the same conditions were observed. This latter point is significant and will be referred to later.

There is also at least one statement based on a quantitative investigation of the priming of large power plant boilers. Mumford in 1929 (7) in his studies of the effect of hydroxyl concentration on moisture in steam, made the following statement: "The effect of the critical concentration of hydroxyl has been the same in boilers just filled with raw water as it was on boilers which had been in the line for weeks, so that the effect of hydroxyl must have been independent of the concentration of suspended matter, which must have varied under the above conditions." The inference here certainly seems to be that suspended matter played a minor rôle.

Finally, advocates of the belief that solids do not always promote priming can point to the fact that in the earlier papers (prior to 1927) very few are to be found in which all the conditions are carefully described and taken into account, and in at least one case an investigator's zeal blinded him to the effect of a very obvious condition in his experiment.

In short, there is a growing amount of evidence in favor of the opinion that suspended solids frequently have little or no effect on priming. How now can these opposite views be brought into line? Are there not some reasons other than faulty observations to account for the situation? The author believes that there are such reasons and offers the following evidence to show that both views may be correct, depending on conditions.

ADDITIONAL EVIDENCE

1. In repeating the work of Joseph and Hancock the experiments at Ohio State were arranged to test a hypothesis suggested in a paper by Foulk and Hansley (8) who had shown in 1932 that certain solids lost their foam stabilizing properties on several hours' boiling in a dilute salt solution in an open flask. It was thought that this loss

would be more rapid at the higher temperatures of a boiler. The results published in 1934 (6), proved this supposition to be true. The Ohio State Joseph and Hancock boiler was equipped with a device by which the solid matter (ground limestone) could be added after the boiler had reached its operating pressure and temperature. When the experiments were made in this way the solids increased the priming, the effect being especially strong at the lower pressures. The priming tendencies were however lost in five to ten minutes contact with the hot boiler water, the rate of loss being greater the higher the temperature (pressure).

This rapid loss of foam stabilizing effect has an important bearing on Joseph and Hancock's experiments which were made by putting the solid material into the cold boiler and then heating it up to pressure. The time required to bring the boiler to 150 pounds pressure was so long and the temperature of the water during a large part of the time was so high, that the solid matter lost its effect.

2. Not all kinds of solid matter, even if very finely divided, increase the foaming of salt solutions or the throwing of water into the steam lines. It has been shown at Ohio State (6, 8), for example, that ground flint which is nearly pure silicon dioxide, is such a solid. When put into an experimental boiler at 150 pounds pressure it not only did not increase the priming, it materially reduced it. Ground flint is of course not a compound found in boiler waters, but having discovered that it behaves as it does, one naturally wonders whether some regular boiler solids may not behave the same way. This behavior of ground flint appears to be independent of the temperature.

3. Experiments have also been made at Ohio State on the effect on foaming of boiler scale containing oil (8). After the oil was extracted, the foam stabilizing properties were largely lost. These experiments were made in glass flasks. The results are significant because in the early days of reciprocating engines oil was used in the cylinders and if condensed steam was returned to the boiler the sludge absorbed oil and thus became a foam stabilizer. The effect on priming, however, depended on the rate at which the sludge took up oil as compared with the rate at which it lost the oil to the hot boiler water.

4. The effect on priming of solid matter is less at higher than at lower pressures. This is brought out in the paper by Foulk and Whirl (6). The falling off of carry-over with increase of pressure is,

however, probably not a function of the solid matter. Recent experiments in the author's laboratory show that the carry-over of a sodium chloride solution is materially less at 150 than at 250 pounds pressure.

Most of the evidence cited above is based on the effect of solid matter added to the boiler water. This is only half of the picture because most of the suspended solids in a boiler are produced in it by chemical precipitation. The effect of solids produced inside a boiler might be quite different from that of solids added from the outside and therefore an extensive investigation of this point has been carried out in the author's laboratory (9). The work was done in a small water tube boiler operating at 250 pounds pressure. This little boiler is a replica of the one described by Christman, Holmes and Thompson (10). The following results of the investigation are presented below.

5. That commonest of boiler solids, calcium carbonate, was found to vary in its effect according to the way it is precipitated in the boiler and according to the time of contact with the boiler water. For example, if the calcium carbonate is precipitated by the decomposition of calcium bicarbonate inside a boiler operating at 250 pounds pressure (205°C., 401°F.), it decreases the priming of a salt solution. If the carbonate is precipitated by pumping sodium carbonate solution into a boiler containing calcium chloride, in other words, if the precipitate forms in an excess of calcium chloride, the results are inconclusive. On the other hand, if the calcium carbonate is thrown down by pumping calcium chloride solution into the boiler containing an excess of sodium carbonate the precipitate increases the priming, and if, now, this precipitate which promotes priming is kept in the operating boiler for four or five hours it not only loses its effect as a promoter of priming, it actually reduces the priming. This effect has also been observed by Holmes (11) in the case of sludge precipitated by concentrating a natural water in his experimental boiler. Holmes called the phenomenon "aging of the sludge." It is thus seen that this form of calcium carbonate can increase priming, have no effect on priming or can decrease priming, depending altogether on the length of time it is in contact with the hot boiler water.

6. Magnesium hydroxide, also a common precipitate in a boiler, was shown to reduce priming, and if thrown down in sufficient quantity along with that form of calcium carbonate which increases

priming, it counteracts the effect of the carbonate, so that by selecting different ratios of carbonate and hydroxide one can have a positive or negative effect, or no effect at all on the priming of the salt solution in the boiler.

GUIDING PRINCIPLE OF SMALL SCALE EXPERIMENTATION

Before coming to the final conclusions of this paper, the author would like to state the principle which he has been following in his boiler water studies at Ohio State. It is to create a background of information by investigating, one at a time and under controlled conditions in an experimental boiler, the important factors that affect the carry-over of liquid water into the steam. This studying of one factor at a time cannot be done to advantage in a commercially operating boiler, because the conditions are not so well under control and there is therefore no method of determining the effect of one condition by itself. There can be no scientific understanding of the effect of suspended solids, for example, without the knowledge that some kinds of solid matter reduce priming and other kinds increase it. Such knowledge can be obtained only by patiently trying one substance at a time.

The question of course arises as to whether the behavior of water in an experimental boiler is the same as in a large commercial one. Only a large number of direct experiments can answer this question, and it would perhaps pay to make a few of the more important ones. The experiment of Joseph and Hancock with a locomotive boiler cited above is the only published case in point.

That there should be direct agreement between the results of small laboratory and commercial boilers is, however, not so important as it seems, because the main purpose of the small scale experiments is to study the behavior of individual substances with the view of suggesting new ideas that may eventually help in solving some puzzling situation in actual practise. At any rate the author prefers to have his experimental work considered from this standpoint.

DEDUCTIONS FROM THE EVIDENCE

On studying the above group of facts as brought out by experiments with glass flasks and small laboratory boilers, three points bearing on this question of the effect of solid matter stand out.

- (1) Some kinds of solid matter increase priming, some kinds have

no effect, and some kinds actually decrease priming. Examples of the above have been found among solids added from the outside and among solids precipitated inside an operating boiler.

(2) Some kinds of solid matter that cause priming when first introduced into the boiler or when first precipitated inside the boiler, lose that property on sufficient time of contact with the hot boiler water. The rate of loss in the case of solid matter added from the outside is more rapid the higher the temperature. The same is probably true of solids precipitated inside the boiler but such an experiment has not yet been tried.

(3) Priming in general is greater at low than at high pressures.

Consideration of these three points shows that the question of solid matter should not be asked as formerly,—does solid matter in the boiler water increase priming, but rather in this way—what kinds of solid matter increase priming, and under what conditions? The following is perhaps worth stating as a working hypothesis. At low pressure, which means also low temperatures, suspended solids may and frequently do increase priming, but at high pressures and temperatures the effect is less and is frequently absent.

This hypothesis is in harmony with flask experiments which were made at 100°C. At higher temperatures (pressures) the solids may lose their foam stabilizing properties so rapidly that it will not be evident that they ever had such properties. In the early days of steam engineering when 50 pounds pressure was used and, incidentally, when feed waters were not as good as now, it is at least a fair guess that suspended solids in the boilers nearly always promoted priming, and perhaps the opinions formed in that early day persist to the present.

Obviously much more work must be done before a proper understanding of conditions will be attained. The final answer then will be, either a method for the elimination of the undesirable conditions or a method for counteracting the effect of those conditions.

GENERAL ASPECTS

Let us now examine the general aspects of the question to see if there is any explanation for the fact that solids at low pressures and temperatures cause priming and at higher pressures and temperatures lose this property. The answer is, that this is in harmony with existing theory. Foam is not stabilized by solid matter unless the solid matter floats and the floatability is inversely proportional to

the wettability of the solid. Ground flint, for example, is instantly wet by water solutions and sinks. It cannot have any effect on the foam because the foam is on the surface. On long boiling, the wettability of a solid that initially floats is increased, it sinks and therefore can no longer stabilize the foam bubbles. This increase in wettability proceeds faster the higher the temperature, and therefore in a modern steam boiler in which the temperature of the water is 200°C. or higher, most solids become instantly wettable. The form of calcium carbonate which, as stated above, retains its priming tendencies for hours is apparently an exception to this rule. There is no explanation for this at present. The fact that the gelatinous precipitate of magnesium hydroxide does not increase priming is assumed to be due to its wettability. It must, however, be confessed that no studies have as yet been made of the relative wettability, or floatability, of precipitates in a steam boiler.

The reason why some precipitates actually decrease priming is not so easy to explain. It is, however, in line with what every chemist knows about the prevention of bumping in liquids boiling in glass vessels. Bumping is violent ebullition and can be lessened or prevented by introducing certain kinds of solid matter into the liquid. The action is usually explained by assuming that the solid matter carries entrained air on its surface which thus furnishes a gaseous nucleus so to speak at which boiling goes on and prevents superheating. It is doubtful, however if this explanation applies to precipitates formed inside a boiler. At any rate, whatever may be the fundamental reason, the observed fact that in the Ohio State experimental boiler, priming was reduced by certain forms of solid matter is not out of harmony with experience in the boiling of liquids in glass vessels at atmospheric pressure. In the Ohio State experiments the loss of priming effect on the part of one of the forms of calcium carbonate was accompanied by a change in physical characteristics. It became more crystalline and granular.

The fact that in experimental boilers (three widely different designs have been used at Ohio State) certain forms of solid matter actually reduce priming seems to be new. The author asks his more practical engineering friends if they have encountered such experiences with commercial boilers.

(Presented before the Boiler Feed Water Section meeting of the American Society of Mechanical Engineers, December 5, 1935.)

LITERATURE

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PURIFICATION METHODS AT NEW ORLEANS

By CARL C. FRIEDRICH, JR.

(The Sewerage and Water Board, New Orleans, La.)

The purification plant at New Orleans was first put into operation in the early part of February, 1909. It was designed for a normal load of 40 m.g.d. with a maximum capacity of 60 m.g.d. The original plant consisted of two plain subsidence basins, or grit basins, with a capacity of 3.3 million gallons each; two mixing basins with a 2.5 million gallons each, which allowed one and one-half hours for mixing and floc formation; four settling basins with a combined total capacity of 30 million gallons, and a 30 million gallon clear water reservoir that was to serve as a reserve supply. The Head House, from which the entire system was controlled, and where the chemicals were stored and fed into the water, together with a filter gallery composed of ten units, each with a normal capacity of 4 million gallons, made up the system. This plant was sufficient for the City demand until the early twenties, when its capacity was taxed on a number of occasions.

These periodical overloads eventually brought about the enlargement of the plant to its present size. Construction work was started in 1927, and during the latter part of 1932 the new plant plus the additional reservoirs and filters, was being entirely utilized.

These additions raised the normal capacity of the plant to 112 m.g.d. The new grit basins have a capacity of 10 million gallons each, the mixing basins 4.5 million gallons each, and the four additional settling basins raise the settling capacity to 77 million gallons. Eighteen new filters were constructed, bringing the total number of these units to twenty-eight.

The new plant was largely modeled after the old, the principal differences being in the equipment for handling and storing chemicals, and the method used for governing the chemical feed. In the old plant the latter was accomplished by passing the water through submerged orifice gates, the loss of head through the gates being transferred by a series of floats to a proportional head over a variable orifice, through which the chemicals in solution were fed. In the new plant this is done by using the differential of a Venturi Tube.

RAW WATER

The Mississippi River, from which the supply comes, has a watershed of approximately 1,240,000 square miles. It is a clay-bearing stream, and one of its principal characteristics is the constant presence of exceedingly fine clay particles carried in suspension. On occasions it has been noted that the suspended matter in the raw water was probably 70 percent or more in the colloidal state, and when left standing bottled up for a period of one week, the surface layers of this water were found to have a turbidity of only 5 percent less than the original sample.

The drainage basin of the river embraces six natural divisions, each one differing from the other in many ways. These divisions are: The Ohio Basin; the Upper Mississippi Basin; the Missouri Basin; the Arkansas Basin; the Red Basin, and the Central Valley.

The character of the river at New Orleans at all times shows the predominance of one or another of the tributaries, which fact causes wide variations in the water; not so wide, however, as in the case of many of the tributaries themselves.

These variations are quite natural when one stops to consider the vast differences in the character of the areas drained; the limestone country of Kentucky and Tennessee; the black bottoms of the Dakotas; the fertile plains of the Central West, and the swamp lands of the Central Valley itself.

An analysis of the river at New Orleans is as follows, in parts per million:

	Maximum	Minimum	Average
pH value.....	8.1	7.7	7.9
Turbidity.....	2000	50	420
Alkalinity.....	175	45	100
Total hardness.....	225	60	130
Free CO ₂	8	0	1
Calcium.....	50	24	35
Magnesium.....	20	6	9
Bacteria per m.l., 37° for 24 hours.....	50,000	300	3,200
M.P.N. of B. Coli per 100 m.l.....	24,000	23	2,200

The plant is situated about three-quarters of a mile from the banks of the river, at the extreme upper end of the City. The low service pumps deliver the water to the plant through two 48-inch mains. It first enters the grit basins, where it is retained for approximately nine hours, depositing on an average, 10 per cent of the suspended

matter by plain subsidence, the maximum reduction being 40 and the minimum zero per cent.

After this period of plain subsidence, the water passed on to the mixing basins through a concrete conduit in which is located a Venturi Tube. As was previously mentioned, this tube governs the proportioning mechanism for the chemical solution feed, at the same time registering and recording the rate of flow.

CHEMICAL TREATMENT

The coagulants in use at New Orleans are ferrous sulphate with lime. All chemicals are fed to the water in solution.

The milk of lime is applied to the water immediately upon entering the mixing basin, the dose varying considerably with the changing character of the raw water, and while pH values are determined at numerous points throughout the system, the older method of alkalinity titrations is relied upon to a much greater extent for the control of the lime dosage, and the subsequent softening and floc formation.

The mixing basin is of the conventional end around end type, the mixing time averaging two and one-third hours in all. The sulphate of iron solution is added at the half-way point, after the lime has become thoroughly mixed and its softening reactions completed. In other words, the lime mixing and softening take place in the first half of these basins, and the floc formation in the second half.

After the iron has been applied, the water passes over and under a series of baffles for twenty feet, giving it a violent turbulent mix for two or three minutes. It then decreases to a minimum flow for floc formation, this flow being about one foot per second. The time allowed then for floc formation is one-half the total time in the basin, or one hour and ten minutes at the present rate of purification.

On an average, 4.33 grains per gallon of lime, and 0.5 grain per gallon of iron sulphate are required for proper treatment.

After coagulation the water enters the settling basins. These basins are of the cross baffled type, the water entering one side of the reservoir, traveling its entire length, then flowing over a skimming weir, returning down the other side, and finally being drawn off over a second skimming weir at the effluent. The average period of retention in the basins is 20 hours, the turbidity rarely ever exceeding 8 p.p.m. at the outlet.

Upon leaving the settling basins, the water is carried to the filters through two 60-inch welded steel pipes, the distance traveled being

approximately 600 feet. This long flow and the consequent loss of head is utilized in proportioning the ammonium sulphate and the chlorine. Because of the fact that the ammonia is applied just before entering, and the chlorine just after leaving these pipes, it is advantageous to use this loss of head as a proportioning control. It was found necessary to add the chlorine previous to filtration, in order that sufficient time will have elapsed for the sterilizing effect of the chloramines.

It has the added advantage of preventing excessive bacterial loadings in the filters and keeps them sightly at all times.

The ammonium sulphate is fed in solution through a variable orifice. The head over this orifice is controlled through a system of balanced floats, which in turn respond to another system of floats, actuated by the loss of head through the 60-inch pipes. This loss of head also throws up in direct proportion to it, a counter-balancing head of clear water over a small fixed orifice. The flow from this orifice is utilized through converters to control the chlorine dosage.

The chlorine is fed in such amounts as to maintain a residual of 0.5 p.p.m. in the finished product. The chlorine ammonia ratio is four to one. This amounts to 6.25 pounds per million gallons for the chlorine, and 6.50 pounds per million gallons for the ammonium sulphate, on an average.

The use of ammonia at New Orleans is comparatively new, being used only for the past two years. Its use was prompted by the occasional occurrence of chloro-phenol tastes, and also because of its persistent sterilizing action all through the distribution system.

FILTRATION

After chlorination come the filters. The rate of filtration averages 95 m.g.d. per acre. This rate is considerably lower than the normal rate for which these filters were designed, and, therefore, long filter runs are obtained. Sometimes the runs are as long as 450 hours. The average is 275 hours, and the average wash water used is 0.3 percent.

The clear water reservoir was used originally as a reserve supply, but with the additions of the last few years, this reserve was found to be unnecessary. It was decided, therefore, to use the reservoir to smooth out the rate of flow through the system. During the night and early morning hours when the consumption is low, the surplus water is stored away. Then when the heavy demand sets in the supply is drawn on, thereby avoiding the necessity of increasing

the rate through the plant. With careful attention on the part of the operators, they are at times able to operate for 72 hours or more without a change of rate, avoiding altogether the sudden changes of rate which might prove detrimental to good filtration.

The average turbidity of the finished water is 0.2 p.p.m. It is never allowed to exceed 0.5 p.p.m. The bacterial quality is well above the standard. The 37° count after twenty-four hours averages 2.0 per m.l. The most probable number of *B. Coli* present in one hundred m.l. is infinitesimal, having been confirmed only on three occasions in the past year.

The cost of chemicals per million gallons for this treatment is as follows:

	dollars
Lime.....	2.04
Sulphate of Iron.....	0.48
Sulphate of Ammonia.....	0.09
Chlorine.....	0.23

The total cost of purification and pumping per million gallons of water, excluding improvements and additions, was \$15.34 for the year 1934.

The lime and iron process was adopted by the original investigators at New Orleans, as the most satisfactory of various coagulants investigated.

On two or three occasions since then, other coagulants have been experimented with, but up until this time none has been found that would give more satisfactory results at an equivalent cost.

Much experimental work was done about three years ago to determine if it were not possible to use pH control exclusively. It was found at that time, and our experience in the ensuing years has borne this out, that the most satisfactory floc was not always formed at the same pH value. At times a very satisfactory floc was obtained with values as low as 9.0; at other times it was found necessary to go as high as 9.4; on a few occasions the optimum was found to be 9.5.

At the present time, chlorinated copperas as a coagulant is being investigated; up until now, however, nothing conclusive has been brought out.

While the process of purification is primarily the same as was originally adopted, the methods of treatment have been changed from time to time, and will continue to change as newer and better ideas present themselves.

(Presented before the Southwest Section meeting, October 14, 1935.)

REPORT OF THE SECRETARY FOR YEAR ENDING DECEMBER 31, 1935

STATEMENT OF FINANCIAL CONDITION

ASSETS	
Cash on Hand.....	\$384.82
Accounts Receivable, Dues.....	210.30
Accounts Receivable, Advertising.....	3,681.22
Accounts Receivable, Manuals.....	55.00
Accounts Receivable, Indexes.....	116.50
Accounts Receivable, Censuses.....	31.50
Inventory, Manuals.....	45.00
Inventory, Indexes.....	244.50
Inventory, Index type metal.....	250.00
Inventory, Censuses.....	49.50
Investments.....	33,848.65
Office Equipment (depreciated).....	1,495.61
Accrued Interest on Investments.....	288.42
Total Assets.....	\$40,701.02
Deduct:	
Accounts Payable Manuals.....	45.05
Total Assets Representing Surplus.....	\$40,655.97

SURPLUS	
Balance January 1, 1935.....	\$40,722.36
Sundry adjustments, inventories, accrued interest, etc.....	402.75
	40,319.61
Profit on 1935 Operations.....	336.36
	\$40,655.97

STATEMENT OF INCOME AND EXPENDITURE

INCOME	
Annual Dues.....	\$27,577.79
Advertising.....	15,753.25
Subscriptions to Journal.....	2,634.49
Sales of Proceedings.....	370.91
Sales of Specifications.....	91.60
Sales of Manuals.....	265.00

Royalties on Manual Sales.....	\$90.00
Sales of Reprints.....	938.99
Sales of Census.....	13.50
Sales of Index.....	165.44
Interest on Investments.....	1,842.50
Interest on Deposits.....	56.23
Convention Registration Fees.....	3,986.28
Convention Entertainment Tickets, Sales.....	1,254.00
Annual Payment by Water Works Manufacturers Association.....	7,500.00
Refund of Expenses Advanced to American Public Health Assoc. (Publication of Standard Methods of Water Analysis)—Year 1934.....	74.18
Profit on Sale of Standard Methods of Water Analysis—Year 1934 (portion due A. W. W. A.).....	498.10
Refund by American Committee on Electrolysis of Balance Cash on Hand (portion due A. W. W. A.).....	107.05
Sundries.....	82.19
Total Income	\$63,301.50

EXPENDITURE

Convention Entertainment Expense.....	\$4,977.26
Convention Expense (general).....	1,754.94
Office Expense.....	6,105.31
Committee Expense.....	1,600.12
Section and Division Expense.....	3,188.50
Directors' Meetings.....	1,698.31
Salaries.....	24,300.00
Printing Journal.....	15,558.18
Reprints, Purchases for re-sale.....	848.39
Specifications, Purchases for re-sale.....	16.00
Manuals, Purchases for re-sale.....	236.25
Membership Dues in Other Organizations.....	460.00
Sundries.....	69.31
Preparation of Specifications for Steel Pipe, Sub-Committee 7-A.....	485.27
Committee on Publicity, Attendance and Membership.....	1,411.12
Depreciation, Office Equipment.....	166.18
Purchase of Franklin Henshaw Cup.....	90.00
Total Expenditure	\$62,965.14

Excess of Income over Expenditure for Year Ending 12/31/35.....	\$336.36
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I certify that the above two statements are in accordance with the books and correct.

(Signed) A. B. DORER,
 Certified Public Accountant,
 170 Broadway, New York, N. Y.

Membership statement

	ACTIVE	CORPORATE	ASSOCIATE	HONORARY	TOTAL
January 1, 1935.....	1,973	209	157	11	2,350
Gains:					
New Members.....	525	25	12	3	565
Restored.....	40		2		42
Transferred.....				1	1
	2,538	234	171	15	2,958
Losses:					
Resignations.....	49	9	6		64
Deaths.....	19			2	21
Dropped for Non-Payment of Dues 12/31/35.....	175	7	8		190
Transferred.....	1				1
Total Losses.....	244	16	14	2	276
Total December 31, 1935.....	2,294	218	157	13	2,682
Total January 1, 1935.....	1,973	209	157	11	2,350
Gain in Year 1935.....	321	9		2	332

Comparative statement—Gains and losses—eight-year period

YEAR	NEW	RESTORED	RESIGNATIONS	DEATHS	DROPPED FOR NON-PAYMENT OF DUES	GAIN OR LOSS	TOTAL MEMBERS AT END OF YEAR
1935	565	42	64	21	190	+332	2,682
1934	271	66	64	22	122	+129	2,350
1933	168	56	132	27	234	-169	2,221
1932	117	22	141	28	297	-327	2,390
1931	203	22	98	25	216	-114	2,717
1930	501	39	95	26	134	+285	2,831
1929	314	25	94	24	130	+91	2,547
1928	203	36	86	13	126	+14	2,456
Totals—8-year period	2,342	308	774	186	1,449	+241	

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the journal.

The Differential Coli Identification by Means of the Neutral Red Reaction with Reference to the Reduction-Oxidation Potential. O. ACKLIN and R. VUILLEMIN. *Mitt. Lebensm. Hyg.*, 25: 138-61, 1934. From *Chem. Abst.*, 28: 4763, August 10, 1934. The pH value can fail, as with typhoid bacillus, to bring about neutral red reaction, rH relationships not having been fulfilled. Paratyphoid A and B bacilli show positive fluorescent reaction with neutral red; reaction is, however, typical only with coli bacillus in dextrose nutrient agar. Neutral red reaction is of great practical significance for differentiation of coli from coliform and typhoid bacilli and is to be looked on as expression of certain oxidation-reduction conditions.—R. E. Thompson.

Effect of Colloidal Graphite on the Corrosion of Boiler Plate. N. A. IZGAR-VISHEV and A. S. SMIRNOV. *Mineral. Suir'e*, 9: 3, 43-4, 1934. From *Chem. Abst.*, 28: 4809, August 10, 1934. Cleaned strips of boiler plate were suspended in autoclave charged with 3 liters Moscow tap water and heated 6 hours each day for 30 days at 180° (8 atmospheres pressure) with and without addition of 0.01 gram graphite stabilized with oak extract. Before weighing, plates were cleaned by immersion in 1 per cent acetic acid for 2 minutes, then rubbed with soft hair brush, washed, and dried. Mean losses of weight per day per centimeter were: tap water alone (hardness 10°) 0.000016, with graphite 0.000021; tap water treated with permutox (hardness 0°) 0.000025, with graphite 0.000032 gram. Corrosion proceeded regularly without pitting and was not affected by periodical cleaning of surface. Permutox treatment accelerates oxidation. Corrosion was 30 to 40 per cent greater in presence of graphite, but was still negligible.—R. E. Thompson.

Greensand. PAUL M. TYLER. *Bur. Mines Information Circ. No. 6782*, 8 pp., 1934. From *Chem. Abst.*, 28: 4816, August 10, 1934. General information including description, uses, occurrence, etc., and zeolite water softening.—R. E. Thompson.

The Importance of Artificial Lakes in the Natural Purification of the Ruhr. F. SIERP and HAYO BRUNS. *Gesundh.-Ing.*, 57: 199-206, 1934. From *Chem. Abst.*, 28: 4809, August 10, 1934. The Ruhr supplies water, receives sewage and industrial wastes, and provides bathing places. Three lakes have been

constructed along its course to improve natural purification and 5 more are planned. Effect of Lake Hengstey, with surface area of 1.6 square kilometers and retention period of about 30 hours, on condition of river water is reported in considerable detail. Lake is just below junction of the Lenne, which carries acid water high in iron (11 p.p.m.), and the Ruhr, whose water, owing to large amount of sewage contained, is alkaline (iron 4 p.p.m.). On mixing, large amount of iron is precipitated as hydroxide, which serves to flocculate much of sewage and cause it to settle during very slow flow through lake. Average values for water entering and leaving lake, respectively, are: sludge content, 45 and 2.5 cc. per cubic meter; weight of plankton, 2217 and 81 milligrams per liter; iron, 8.9 and 3.3 p.p.m.; total bacteria, 46,000 and 23,000 per cubic meter; and *Es. Coli*, 60 and 27. Biochemical oxygen demand is reduced 57 per cent, phenol compounds 54 percent, and there is marked, but variable, increase in carbon dioxide. Table gives yearly averages for period 1928-32. Sludge is removed by flushing annually at times of high water. Lake has been stocked with fish, which have grown satisfactorily and are important factors in natural purification.—*R. E. Thompson.*

Simple Apparatus and Tests for Efficient Control of Water Softeners. P. J. GOODYER. *J. Soc. Dyers Colourists*, 49: 345-6, 1933. From *Chem. Abst.*, 28: 5156, August 20, 1934. WANKLYN's standard soap solution gives more accurate results than CLARKE's lead oleate solution. Special or mixed indicators are recommended for alkalinity determination. Method of calculating necessary combination of materials for treating water of given hardness and alkalinity described.—*R. E. Thompson.*

The Deterioration with Age of Concrete Gravity Dams. G. WESTERBERG. First Intern. Congr. Large Dams, Stockholm 1933, Question 1A, Rept. No. 3, 33 pp.; Bldg. Sci. Abstracts 7: 126. From *Chem. Abst.*, 28: 4855, August 10, 1934. Disintegration by water percolating through concrete is dependent not only on chemical composition of water, but also on rate of flow. Water with high free carbon dioxide content is very destructive, whereas neutral water, especially if lime content is high, may actually improve water tightness. Analysis of water which had leaked through concrete showed high calcium hydroxide content and also that amount of hydroxide so leached from young concrete may be as much as 1 gram per liter of water. The longer leakage continues, the lower is proportion of lime dissolved, but the greater is the leakage. In presence of carbon dioxide, dissolved lime reacts to form relatively insoluble carbonate, and on downstream side of dam atmospheric carbon dioxide reacts similarly and thus assists in making surface less permeable. In construction of concrete dams, dense impermeable concrete should be produced and care should be taken in grading of both fine and coarse aggregate. Some consideration is given to methods of repairing damaged structures.—*R. E. Thompson.*

Disinfection of an Aftergrowth in Tropical Drinking Water. J. K. BAER. *Ref. Zentr. Hyg.*, 29: 763-4, 1933; *Wasser u. Abwasser*, 32: 18. From *Chem. Abst.*, 28: 5158, August 20, 1934. Bacterial count remained high

even though excess of 0.1 p.p.m. chlorine was maintained. Iron dissolved from pipes and manganese from added potassium permanganate formed colloids which protected bacteria. Used of chloramine reduced by 90 per cent development of bacteria in settling basins. Chloramine, though weaker, retained activity for longer time.—*R. E. Thompson.*

Clinical Significance of Traces of Fluorides in Water. N. J. AINSWORTH. *Analyst*, 59: 380-5, 1934. From *Chem. Abst.*, 28: 5155, August 20, 1934. Clinical observations with respect to mottled teeth in children given.—*R. E. Thompson.*

Determination of Fluorine in Silicate Rocks and in Water. OSKAR HACKL. *Z. anal. Chem.*, 97: 254-8, 1934. From *Chem. Abst.*, 28: 5005, August 20, 1934. Review of known methods with critical comments.—*R. E. Thompson.*

Determination of Small Quantities of Fluorides in Water. GUY BARR and A. L. THOROGOOD. *Analyst*, 59: 378-80, 1934. From *Chem. Abst.*, 28: 5155, August 20, 1934. To 50 cc. water in Nessler tube add 2.5 cc. concentrated hydrochloric acid and sufficient reagent to impart pale pink color after 10 minutes and compare with standards. Reagent is mixture of 3 cc. solution containing 3.53 grams $ZrOCl_2 \cdot 8H_2O$ in 100 cc. water and 1 cc. of 1 per cent sodium alizarinmonosulfonate in water.—*R. E. Thompson.*

The Purification of Waste Water from the Cheese Factory. A. ARTUS. *Lait*, 14: 478-83, 1934. From *Chem. Abst.*, 28: 5145, August 20, 1934. Treatment with alum and lime yield clear, limpid water that can be disposed of without pollution of body of water into which it is allowed to flow.—*R. E. Thompson.*

Physical and Chemical Methods for the Control of Mineral Waters. ARMAND and LANQUET. *Ann. mines*, 13: 5, 69-78, 1934. From *Chem. Abst.*, 28: 5156, August 20, 1934. Sampling and verification of analysis by summation are discussed. Because of lack of constancy and precision, free carbon dioxide should not be considered with other determinations. Alkalinity is determined by titration with 0.1 normal sulfuric acid with erythrosin in presence of ether as indicator. Analysis can be checked by measurement of electrical resistivity. If calcium is kept in solution by saturation of water with carbon dioxide, resistivity of synthetic solutions checks that of natural water.—*R. E. Thompson.*

Manganese Removal from Leipzig Water Supply. L. KAATZ and H. E. RICHTER. *Gas- u. Wasserfach*, 77: 291-4, 1934. From *Chem. Abst.* 28: 5155, August 20, 1934. Theory of manganese removal is discussed. Manganese salts are adsorbed by manganese dioxide or its hydrated form and oxidized to manganic compounds, eventually forming manganese dioxide, which forms catalytic layer on surface of filter material. Experiments indicated that manganese content of Leipzig water could be reduced to less than 0.05 p.p.m. In making new filter, at least 20 per cent previously "worked-in" sand should be mixed in, or initial rate of filtration will be too slow. Filtration rate may be

5 to 6 meters per hour at first and then increased to 20 when sand becomes coated with active material. Water should be practically neutral for best results, high pH causing lime deposits. At times, oxidizing power of filter must be increased by adding oxidizing agents, even though sufficient oxygen is available in water to oxidize manganese. Filter must be washed carefully to avoid removal of active manganese layer.—*R. E. Thompson.*

Disinfection of Drinking Water. J. K. BAARS. Mededeel. Dienst. Volksgesondheid Nederland.-Indië, 23: 1-5, 1934. From Chem. Abst., 28: 5155, August 20, 1934. Disinfecting power of chlorine and of monochloramine was investigated. From series of tests for periods of 10 minutes to 24 hours with 0.2 p.p.m. chlorine or monochloramine at pH 5, 6, 7, 8, and 9 and with addition of 500,000 colon bacilli per cc., general conclusion is that sterilization by both is equally good. At pH 8 and 9 chlorine acts somewhat more rapidly; in acid medium, monochloramine is a little faster, but after 24 hours disinfection is complete with both agents. Monochloramine has advantage of being cheaper; less active chlorine is taken up by organic matter; phenol tastes are prevented; and sterilization is more permanent.—*R. E. Thompson.*

Determination of Minor Constituents of Natural Mineral Waters. L. FRESSENIUS. Z. deut. geol. Ges., 85: 540-4, 1934. From Chem. Abst., 28: 5557, September 10, 1934. Application of spectroscopic methods discussed.—*R. E. Thompson.*

Flocculation of Bicarbonate Waters. ARMAND and LESCOEUR. Ann. mines, 13: 5, 79-81, 1934. From Chem. Abst., 28: 5156, August 20, 1934. Within one-half hour turbidity may develop in clear water which results in deposit at bottom of container, leaving water again clear. Flocculation is not caused by loss of carbon dioxide, but is due to oxygen of air and can be prevented by keeping water in inert atmosphere. Flocculation is explained as due probably to presence of ferrous salts. Electrical conductivity of decanted water is not modified by more than 1 or 2 parts per 100.—*R. E. Thompson.*

Study of Boiler Waters in High-Pressure Plants. D. B. KEYES. Trans. Illinois State Acad. Sci., 26: 77, 1934. From Chem. Abst., 28: 5156, August 20, 1934. Review of STRAUB's work (C. A., 28: 3154). Small amount of sodium carbonate, insufficient to cause embrittlement, will prevent formation of calcium sulfate scale at pressures as high as 2000 pounds per square inch.—*R. E. Thompson.*

The Nitro Effect. A New Method for Evaluation of Water, Sewage, and Sludge. O. ACKLIN. Wasser und Gas, 24: 324-33, 1934. From Chem. Abst., 28: 5156, August 20, 1934. New method for determining chemical, biochemical, and total nitro effects utilizes nitroanthraquinone, which in presence of hydrogen forms red aminoquinone. Depending upon whether test is continued for few hours or few days, chemical, or biochemical plus chemical, effect is obtained. Such compounds as hydrogen sulfide are important in determining chemical effect, while in longer test there is in addition the reducing effect of

hydrogen from biochemical action. Nitro effect depends on (1) number and type of bacteria, (2) temperature and pH conditions, (3) amount and kind of reductants, and (4) dehydrogenation of accelerating or of inhibiting substances. Complete details of theory and use of method given for number of specific cases.—*R. E. Thompson.*

The Velocity of the Reaction of Iron with Cupric Sulfate. S. A. VOZNESEN-SKII and I. T. NAGATKIN. *J. Applied Chem. (U. S. S. R.)*, 7: 51-60, 1934. From *Chem. Abst.*, 28: 5158, August 20, 1934. Velocity of reaction $\text{Cu}^{++} + \text{Fe} \rightarrow \text{Fe}^{++} + \text{Cu}$ was investigated for purpose of obtaining data on construction of equipment for purification of copper-polluted waters by replacing copper with iron.—*R. E. Thompson.*

Water Permeability as a Means of Studying the Corrosion Phenomena in Mortar Masses. H. KÜHL, J. PARGA-PONDAL and S. BAENTSCH. *Zement*, 23: 69-74, 84-9, 100-4, 116-19, 127-30, 141-4, 1934. From *Chem. Abst.*, 28: 5202, August 20, 1934. Percolation studies were conducted on cement-sand mortars of 1:3, 1:5, and 1:8 proportions. The 1:3 mixes cured in air were impervious, while those cured in water showed slight permeability. Leaner mixes showed greater permeability at earlier ages, increase in imperviousness being rapid for moist-cured specimens. Reduction in compressive strength was greatest with mortars of early ages and higher cement contents. Alkalies were leached out first unless they had been removed largely in curing, as in water method. Lime-leaching was greatest with water-cured specimens, because of prevention of carbonate formation. Ferric oxide and alumina were not found in leachings and silica in small amounts only. Sulfate radical appeared in traces only when leachings were high in lime.—*R. E. Thompson.*

Fundamental Facts of Base Exchange. G. AUSTERWEIL. *J. Soc. Chem. Ind.*, 53: 185-9T, 1934; cf. *C. A.*, 26: 1716, 4004; MARSHALL and GUPTA, *C. A.*, 28: 1443. From *Chem. Abst.*, 28: 5309, September 10, 1934. Chief reaction of base exchange is governed by extraction laws, base-exchanger having function of solid solvent, non-miscible with liquid solution of exchanging base. This reaction is limited and governed by laws of mass action and phase rule. There are several minor side reactions, importance of which increases with variation in composition of zeolite and variation in basicity of exchanging cations.—*R. E. Thompson.*

Treatment of Waste Waters from Dyeing with Sulfur Blacks. L. P. MICHEL. *Tiba*, 12: 337-45, 1934. From *Chem. Abst.*, 28: 5245, August 20, 1934. These waste waters contain essentially excess dye, sodium sulfate (or in certain cases, sodium chloride), sodium sulfide, and sodium carbonate. Filtration through adsorbing material (e.g., charcoal, activated sludge, etc.) and treatment with acid or with metallic salts are not considered satisfactory or economical. Following treatment has been in use 3 years at plant discharging into stream having minimum summer flow of 150 cubic meters per minute, eliminating all complaints of stream pollution: ferrous sulfate is added in such amount as to cause considerable (but incomplete) precipitation of sodium sulfide and leave

liquor decidedly alkaline, dilute sulfuric acid is slowly added with constant stirring to practically complete precipitation of dye, lowering of pH below 6 being avoided, and finally liquor is neutralized with slight excess of powdered calcium carbonate and filtered. Cost of treatment can be reduced by utilizing waste waters from oil sulfonation as source of sulfuric acid and by preparing ferrous sulfate by dissolving scrap iron in sulfuric acid.—R. E. Thompson.

Purification of Gas-Works Waste Water. A. C. TAYLOR. *Gas World*, 100: 713-14, 1934. From *Chem. Abst.*, 28: 5211, August 20, 1934. Water from tar separator of Reading, Pennsylvania, water-gas plant is treated with sodium carbonate and copperas, settled, and filtered through coke and coarse sand. Effluent is suitable for discharge into Schuylkill River.—R. E. Thompson.

Nephelometric Titration of the Calcium Ion. E. P. GARMASH. *Zavodskaya Lab.*, 1933, 8, 13-14. From *Chem. Abst.*, 28: 5366, September 10, 1934. To cylinders containing 10 to 15 cc. of saturated ammonium oxalate, add stabilizer (2 to 5 cc. 10 per cent ammonia and 1 or 2 cc. 0.1 per cent gelatin) and water to make 50 cc. To one cylinder add unknown and to the other, standard solution until turbidity is almost same. Add water until volumes are equal and continue titration to completion.—R. E. Thompson.

Nephelometric Titration of the Magnesium Ion. E. V. VASIL'eva. *Zavodskaya Lab.*, 1933, 8, 10-13. From *Chem. Abst.*, 28: 5366, September 10, 1934. In pure salts, magnesium is determined in 15 to 20 minutes with possible error of from 0 to 12 per cent. Other cations are removed by addition of saturated potassium ferricyanide, saturated ammonium oxalate, and concentrated ammonium hydroxide. To each of 2 cylinders are added 10 cc. 0.2 normal trisodium phosphate and 10 cc. ammonium hydroxide (1:9), and mixture is diluted to 50 cc. To one cylinder is added drop by drop from pipet with constant stirring 10 cc. of solution to be tested and mixture is diluted to 80 cc. To other cylinder is added drop by drop, with stirring, standard solution of magnesium sulfate or nitrate until turbidities are nearly same. Volumes are made equal and titration completed.—R. E. Thompson.

Nephelometric Titration of the Chloride Ion. G. T. MIKHALCHISHIN. *Zavodskaya Lab.*, 1933, 8, 14-16. From *Chem. Abst.*, 28: 5366, September 10, 1934. Titration is conducted in nitrate or sulfate medium. A 0.1 per cent colloidal solution of gelatin, not more than 2 or 3 days old, is added for stabilization. Pour from 3 to 8 cc. of unknown (approximately 0.01 normal) into cylinder, add 20 to 30 cc. of water, 4 or 5 cc. nitric acid, and 2 cc. gelatin, dilute to 50 cc., and titrate with 0.1 normal silver nitrate, 1 or 1.5 cc., with constant stirring, against black background. Into another cylinder introduce same substances and in place of unknown add drop by drop standard sodium chloride. Continue titration until turbidities are nearly equal, make volumes equal, and complete titration.—R. E. Thompson.

The Condition of Silicic Acid in Mineral Waters. L. FRESENIUS. *Arch. med. Hydrology*, 10: 81-2, August, 1932; *Chem. Zentr.*, 1933, I, 1491. From

Chem. Abst., 28: 5557, September 10, 1934. Dialysis experiments indicated that amounts up to little less than 1 percent of silica content of waters investigated (and, indeed, of most other mineral waters) were molecularly dispersed, chiefly as dissolved disilicic acid. It is more active therapeutically than colloidal silica.—*R. E. Thompson.*

Rôle of Bacteriophage in Natural Purification. PAUL J. BEARD. *J. Infectious Diseases*, 52: 420-6, 1933. From Chem. Abst., 28: 5557, September 10, 1934. From experiments cited it does not seem possible that bacteriophage is likely to participate significantly in reduction of bacterial numbers in polluted water or sewage, nor does it appear probable that its presence will cause interference, or lead to misinterpretation, in routine tests used in sanitary examination of water and sewage.—*R. E. Thompson.*

Ammonia and the Chlorine-Fixing Power of Water. III. Preammoniation with Ammonium Salts. M. L. KOSHKIN. *Z. Hyg. Infektionskrankh.*, 116: 86-94, 1934; cf. *C. A.*, 27: 4608. From Chem. Abst., 28: 5557, September 10, 1934. Preammoniation with ammonium chloride, carbonate, sulfate, or oxalate, decreases chlorine-fixing power of water, increases bactericidal action of chlorine, and inhibits chlorophenol odor. Other bases than ammonia show little action.—*R. E. Thompson.*

Bath Filtration Systems. E. H. WHITE. *Munic. Eng.*, 93: 608-9, 1934. From Chem. Abst., 28: 5558, September 10, 1934. System so generally used of deep-end outlets and shallow-end inlets is strongly condemned, it being claimed that in baths with 4-hour turnover, some 90 per cent of pollution occurs in shallow end. Improved methods are suggested for delivery and outlet, filtration, and introduction of coagulant.—*R. E. Thompson.*

Lead Poisoning Through Drinking Water. W. KRUSE and M. FISCHER. *Sammlg. v. Vergiftungsfällen, Abt. A.*, 2: 81-2, 1931; *Chem. Zentr.*, 1933, I, 807. From Chem. Abst., 28: 5558, September 10, 1934. In lead epidemic of July, 1930, relation between lead poisoning and water consumption was shown by lead content of 5.3 p.p.m. in samples collected early in morning (which therefore had stood some time). Danger limit is about 0.2 p.p.m. Beneficial results were obtained by treating water with lime to neutralize carbon dioxide.—*R. E. Thompson.*

Lead Poisoning Accompanied by Liver Trouble Caused by Potable Water. R. SCHOEN. *Sammlg. v. Vergiftungsfällen, Abt. A.*, 2: 83-4, 1931; *Chem. Zentr.*, 1933, I, 807. From Chem. Abst., 28: 5558, September 10, 1934. Clinical report of 2 cases of lead poisoning from Leipzig drinking water. For a time, liver disorders were predominant symptoms.—*R. E. Thompson.*

Lead Poisoning by Means of Potable Water in a Case of Diabetes Insipidus. R. SCHOEN. *Sammlg. v. Vergiftungsfällen, Abt. A.*, 2: 85-6, 1931; *Chem. Zentr.*, 1933, I, 807. From Chem. Abst., 28: 5558, September 10, 1934. In case of lead poisoning of woman 41 years old, suffering from diabetes insipidus, by

Leipzig tap water, poisoning symptoms were especially severe.—*R. E. Thompson.*

Determination of Iodide Ions in Hard Drinking Water. JANOS STRAUB. *Z. anal. Chem.*, 97: 259-62, 1934. From *Chem. Abst.*, 28: 5559, September 10, 1934. It has been thought that VON FELLEBERG's method gives low results owing to formation of some calcium iodate (insoluble in alcohol) during preparatory treatment. Careful study, however, shows that this fear is groundless, but that it is necessary to perform repeated extractions with alcohol to remove all iodine when considerable residue of alkaline earth salts is obtained by evaporation.—*R. E. Thompson.*

Supplying Chlorine Gas in Regulated Flow from Cylinders of Liquid Chlorine. FRANZ C. SCHMELKES (to Wallace and Tiernan Co.). U. S. 1,966,265, July 10, 1934. From *Chem. Abst.*, 28: 5564, September 10, 1934. Gas is passed through filter of adsorptive material, such as silica gel, adapted to remove gummy substances, and purified gas then passed through flow-controlling orifice so small in size as to become clogged by gummy substances if present. Apparatus is suitable for use in treating water with chlorine.—*R. E. Thompson.*

Modern Iron Removal Filter Plants. M. J. SHOEMAKER. *Johnson Nat'l. Drillers' Journal* 7: 4, 5, July-August, 1935. All natural waters contain more or less iron. High iron concentrations may cause water to be unpalatable and encourage growth of crenothrix. Four methods for the removal of iron are: (1) aëration and filtration; (2) raise pH and filter; (3) apply potassium permanganate and filter through greensand; and (4) filter through Birm. Birm is a granular mineral which catalytically precipitates dissolved iron as a floe which, in turn, is removed in the filter bed.—*H. E. Babbitt.*

Laws Regulating Well Drilling Now in Effect. Anon. *Johnson Nat'l. Drillers' Journal*, 7: 5, 1, September-October, 1935. Texts of laws in following states are published:—New York, Montana, Wisconsin, and Utah. Reasons for legislative opposition to such laws are given as well as opposition from well drillers. Sound arguments are presented on both sides of the question.—*H. E. Babbitt.*

Hardening and Tempering Drill Bits. Anon. *Johnson Nat'l. Drillers' Journal*, 7: 5, 12, September-October, 1935. Continuation. Discusses methods of hardening and tempering. Right and wrong methods and results are illustrated.—*H. E. Babbitt.*

Climatic Cycles in the West. F. E. BONNER. *Civil Engineering*. 5: 6, 343, June, 1935. No direct relation between sun spots, tree rings, and rainfall has been found. Although considerable time was consumed in conscientious effort to apply beneficially all available data, results were disappointing. During 47 years of subnormal rainfall, sun spots were above the average in 21 years and below it in 26. In the 3 years of normal rainfall, sun spots were above the average in 1 and below in 2. In this simple analysis, the sunspot-

rainfall theory is correct in 41 cases, in error in 41, and undeterminate in 3. For the yellow pine, in years when rainfall was normal, or above, growth was above the average in 23 years and below in 13. With less than normal rainfall, tree rings measured above the average in 18 years and below in 21. This shows 44 hits and 31 misses for the 75 years, or an accuracy of 58 per cent. A similar analysis of the data for the sequoia gives slightly better results.—*H. E. Babbitt.*

Earthquake Effects on Elevated Water Tanks. A. C. RUGE. Civil Engineering, 5: 8, 455, August, 1935. Conclusions reached from model studies. The attempt to apply a theoretical, mathematical analysis to case of tank-tower filled with water is so complicated and impracticable that there remains only the alternative, to make tests on models, or, if feasible, on full-sized structures. Model tests have been made by the Freeman Eng'g Corporation of Providence, R. I. In these tests one is struck by the fact that the elastic limit is reached by very mild accelerations and with ground motions of very short duration. For the most part it was found that two or three equal waves in succession would do almost as much damage to the structure as a long train of equal waves. Until actual earthquake motions can be reproduced, more or less simple laboratory motions must be used and a certain amount of engineering judgment must be applied in interpreting the results. A moderate amount of reinforcing adds very little to, or may even reduce, the ability of the structure to withstand earthquake shocks.—*H. E. Babbitt.*

Colorado River Aqueduct Tunnels. J. L. BURKHOLDER. Civil Engineering, 5: 9, 524, September, 1935. As designed, the aqueduct will carry a flow of 1,605 c.f.s. Tunnels, canals, and conduits are being constructed to full capacity initially, while most of the siphons are being built to one-half of ultimate requirement. Excavation of tunnels is ordinarily effected by the full-face method, using drill carriages. At times it has been necessary to resort to top heading and bench, or to the top-center drift method. Four distinct types of supports, timber, steel, steel ribs with wood lagging, and gunite, are in general use in tunnels. Gunite is used to prevent air-slacking and spalling of the rock rather than to support the tunnel. Both San Jacinto and Valverde tunnels have encountered heavy flows of water. With completion of concrete-lining plants now in progress, it is estimated that the contracting firms and the Water District will have expended more than ten million dollars for plant in the construction of the main aqueduct tunnels, which are estimated to cost \$58,000,000. Over the entire aqueduct an average advance of six feet per shift, or 18 feet per day, has been made at 57 headings.—*H. E. Babbitt.*

Construction of Morris Dam. V. L. PEUGH. Civil Engineering, 5: 9, 549, September, 1935. Advanced methods of handling concrete typify best modern practice. Dam is 328 feet high, 780 feet long, and 280 feet thick at base. The central 300 feet is straight in plan, and the two ends are curved, the radii of the axes being 716.2 feet. Construction of dam involved removal of approximately 600,000 cubic yards of earth and rock, and placing of approximately 500,000 cubic yards of concrete, nearly 5,000,000 pounds of reinforcing steel, and more

than 4,000,000 pounds of gates, valves, pipes, and other metal work. From a construction viewpoint, the chief characteristics of the work were: (1) a short flood season; (2) location within four miles of an existing commercial rock plant; (3) use of an aerial tramway for bringing materials to the job; (4) a concrete plant centrally located between dam and spillway and also readily accessible to the slab on upstream face of west abutment; (5) cement delivered in bulk by tank trucks; (6) cableways for delivering the concrete; and (7) use of concrete too dry to be worked by hand methods, and consequently requiring vibrators. Construction work began April 26, 1932 and the project was entirely finished and accepted on June 12, 1934.—*H. E. Babbitt.*

Large Concrete Pressure Pipes. N. D. WHITMAN. *Civil Engineering*, 5: 9, 553, September, 1935. Until recently, reinforced concrete pressure pipe has been limited to heads under 100 feet. With the introduction in 1923 of cylinder pipe, providing a watertight membrane in the wall with metal joint rings attached, higher internal pressures can be used. The usual allowable working stress in the steel cylinder, or reinforcement, in direct tension is from 12,000 to 13,500 pounds per square inch. Working strength for concrete is usually from 1,200 to 2,000 pounds per square inch. Pipes are made in lengths greater than 5 feet, length being limited by economics. These pipes have a high carrying capacity with HAZEN-WILLIAMS coefficient of 140, or $n = 0.012$ in KUTTER's formula. Many practical problems of design, fabrication, and construction are treated in this article, and excellent illustrations showing details are included.—*H. E. Babbitt.*

Selecting Materials for Rolled-Fill Dams. C. H. LEE. *Civil Engineering*, 5: 9, 556, September, 1935. Traditional manner of determining suitability of material for earth dams is exercise of judgment based on experience, aided by sense testimony such as appearance, "feel" to the hand, and, possibly, grittiness between the teeth. Recent improvements in mechanical equipment for handling earth have so reduced cost of rolled-fill construction that this type is now an economic competitor of the hydraulic fill. The requirements for suitability of material for the impervious part of a rolled-fill earth dam are: (1) permanent stability; (2) reasonable watertightness; (3) workability; (4) insolubility; and (5) reasonable cost. Deciding factor is the clay content, which should slightly exceed that required to fill the voids in the granular part. Selection of material from mechanical analysis data, although believed to be practical, is more or less preliminary in character at the present time and subject to the results of more positive tests, such as those for compaction and permeability.—*H. E. Babbitt.*

Chlorinating Method Improved at Los Angeles. R. L. DERBY. *Civil Engineering*, 5: 9, 558, September, 1935. Article describes sources and possibilities of pollution of Los Angeles water supply. Chlorinating plants are placed at strategic points on aqueducts, reservoirs, wells, and galleries. Chlorination was introduced in 1915 and steady improvement in method of its application has since then followed. The most modern chlorinating plant is shown in illustration. General layout of stations has been standardized and control

of chlorine has been made automatic. At present *o*-tolidin tests are taken twice daily at all stations, the reports being telephoned daily to the central office. Bacteriological samples are taken daily. If these show the water to be safe, chlorination is discontinued after the last rain in the spring. It is resumed when the fall rains produce sufficient runoff to affect the *B. coli* content. Normal chlorine dosages range from $2\frac{1}{4}$ to $2\frac{3}{4}$ pounds per million gallons, with normal residuals of from 0.6 to 0.8 pound per million gallons. With use of ammonia in addition to chlorine, a residual of over 1.0 pound is maintained.—H. E. Babbitt.

Water Conduit Construction in the West. F. C. SCOBEE. Civil Engineering, 5: 9, 569, September, 1935. Since the beginning of the century, the number of new materials and of adaptations of old materials utilized for water conduits has increased many fold. Both open and closed conduits are considered, with special emphasis on methods employed to increase flow capacity. Design values of Kutter's n are suggested for various surfaces. Concrete is the predominating material for lining of earth canals, using $n = 0.014$. Some canals in sandy soils are lined with metal fluming, or with wood staves. Tunnels are sometimes operated as pressure conduits and sometimes as open channels. Heavy steel pipe is now masked in several ways so that it is hard to identify in the field. A pipe somewhat new to this country is made of neat cement and asbestos.—H. E. Babbitt.

Recent Advances in Steam-Plant Design. T. T. EYRE. Civil Engineering, 5: 9, 583. September, 1935. During the past 15 years, there has been a great increase in the thermal efficiency of steam plants. Economies attending use of pulverized coal have stimulated improvements in mechanical stokers to meet this new competition. Furnace temperatures are now about $2,000^{\circ}$ to $3,000^{\circ}\text{F.}$, while steam higher than 800° is seldom used. Overall furnace and boiler efficiencies may attain 90 percent. Numerous plants now operate at pressures of from 600 to 800 pounds per square inch and a few plants, mostly foreign, operate at 1,800 or above. Draft is now forced, obviating the necessity for tall stacks. It is almost universal practice with high-pressure boilers to preheat the feed water by bleeding steam from the turbines. Economizers are used to salvage the high temperatures found in the stack. Impulse turbines and combined impulse-reaction turbines are in common use, with the impulse type slightly advantageous for high pressures. The largest turbine unit at present has a capacity of 208,000 kw. Superheated steam is in almost universal use. Quite recently there have been some successful commercial applications of the binary cycle, mercury seeming to be the most suitable medium when combined with steam. Overall efficiencies of about 34 percent have been obtained with this scheme. Our best plants today are capable of producing a kilowatt hour with the expenditure of but little more than 10,000 B.t.u.—H. E. Babbitt.

A Model Diesel Engine Central Station. H. McCURDY. Civil Engineering, 5: 585, September, 1935. The 37,500 kva municipal plant at Vernon, Calif., is the second largest Diesel installation in the world. Plan and cross section of

the plant are shown in sufficient detail to make clear the general arrangement of both mechanical and electrical equipment. Station is equipped with 5 two-cycle, double-acting, 8-cylinder, mechanical-injection Diesel engines, each rated at 6,850 b.h.p. Article describes details of the operation and control of station, the auxiliary equipment, and the electrical features.—*H. E. Babbitt.*

Springfield Dedicates \$2,500,000 Lake Project. M. DICKINSON. Illinois Municipal Review, 14: 8, 167, August, 1935. Dedication of Spaulding Dam, Vachel Lindsay Bridge, Abraham Lincoln Memorial Gardens, and Lake Springfield. The article gives an account of the 3-day public celebration which marked the inauguration of the new source of water supply for the city of Springfield, Illinois.—*H. E. Babbitt.*

Boron Content of Sea Water of the North Atlantic Coast. NORRIS W. RAKESTRAW and HENRY E. MAHNCKE. Ind. Eng. Chem., Anal. Ed., 7: 6, 425, 1935. Averages found were 4.73 mg. of boron per kg. in 39 samples from south of Cape Cod and 4.75 mg. per kg. in 36 samples from Gulf of Maine. Respective ratios of boron to chloride were 0.00024 and 0.000255. No significant regularity was found in vertical distribution of boron.—*Selma Gottlieb.*

Estimation of Chloramine in Water Supplies. PAUL D. MCNAMEE. Ind. Eng. Chem., Anal. Ed., 7: 5, 333-4, 1935. Chloramine is estimated from increase in ammonium ion (as shown by Nessler reagent) on acidification of sample to below pH 4.4. Test is not as sensitive as *ortho*-tolidine test for free chlorine, but gives good results with 0.2 p.p.m. of chloramine chlorine. Method is especially useful in presence of nitrite, and for differentiating between chloramine and free chlorine.—*Selma Gottlieb.*

Continuous Production of Distilled Water Free from Carbon Dioxide and Ammonia. FREDERICK G. STRAUB. Ind. Eng. Chem., Anal. Ed., 7: 6, 433-4, 1935. Still was fed with heating system condensate plus continuous addition of sulfuric acid and sodium dichromate. Air free from carbon dioxide and ammonia was blown through still. About 40 percent of supply to still was allowed to overflow to waste (pH about 3.5) and remainder was condensed. Conductance was from 0.5×10^{-6} to 0.3×10^{-6} mho, with pH 6.8.—*Selma Gottlieb.*

Occurrence of Selenium in the Colorado River and Some of Its Tributaries. KENNETH T. WILLIAMS and HORACE G. BYERS. Ind. Eng. Chem., Anal. Ed., 7: 6, 431-2, 1935. Presence of selenium up to 0.22 p.p.m. in water of Colorado River and tributaries is due to drainage of irrigated lands, as shown by analyses of drainage waters and soil incrustations. This suggests possibility of improving seleniferous land by irrigation and drainage.—*Selma Gottlieb.*

Preparation of Iron and Steel for Painting. V. M. DARSEY. Ind. Eng. Chem., 27: 10, 1142-4, 1935. Methods in use either (I) do not change surface of metal, e.g., alkali and solvent cleaning; (II) change surface by mechanical

or chemical means, e.g., sandblasting, shotblasting, and pickling; or (III) transform ferrous surface to nonmetallic coating, e.g., ferrous phosphate by Bonderite process. Method to be chosen depends on object and circumstances; but Bonderite process is rapid, is suited for different-sized objects, provides good adhesion for organic finishes, retards electrochemical corrosion, and allows painting to be postponed as desired.—*Selma Gottlieb.*

High-Lime Mortar for Leak-Proof Masonry. FRANK LOFTUS. Ind. Eng. Chem., 27: 10, 1126-7, 1935. High-lime mortar (such as 1:1:6 mix of lime: cement: sand) is recommended for leak-proof properties. It has been successfully used on some of largest New York City buildings and in industrial chimney construction.—*Selma Gottlieb.*

Waterproof Lime. GEORGE B. WOOD. Ind. Eng. Chem., 27: 10, 1125-6, 1935. Rockland Waterproof Lime is a high-calcium, hot-slaking, powdered quick-lime, intimately mixed with relatively small percentage of animal or vegetable fat or oil. It is recommended for water-proof mortar and stucco and washable plaster. This lime is supplied in hermetically sealed multiwall-paper bags with one ply of laminated Cellophane paper.—*Selma Gottlieb.*

Chlorine without Caustic. Anon. Ind. Eng. Chem., News Ed., 13: 413, November 10, 1935. Demand for chlorine has increased markedly without corresponding increase in demand for caustic soda, as produced with chlorine electrolytically. Atmospheric Nitrogen Corp., a subsidiary of Allied Chemical and Dye Corp., is operating pilot plant for making chlorine and sodium nitrate by action of nitric acid on sodium chloride. Within first half of 1936, plant with expected capacity of 25 tons of chlorine and 60 tons of sodium nitrate per day will be ready for operation. Details of method have not been announced.—*Selma Gottlieb.*

Velocity of Large Bubbles in Vertical Tubes. MORROUGH P. O'BRIEN and JAMES E. GOSLINE. Ind. Eng. Chem., 27: 12, 1436-40, 1935. Application is made to water-air lift and oil-gas lift. Experiments were made on air bubbles in water and in two colorless petroleum oils in 3 sizes of glass tubing, largest being 26 feet long by 6 inches diameter. Bubble size was above STOKES' law dimensions. Results showed reasonable agreement with experiments of others at about 3 mm. bubble radius. Disagreement below this size is attributed to condition similar to transition from laminar to turbulent flow in pipes. Above this size, effect of walls of tube becomes noticeable, and finally limiting velocity is reached beyond which no increase results as bubble volume increases. Present work indicates that GIBSON formula for this limiting velocity is slightly high for small tubes and low for large ones.—*Selma Gottlieb.*

Solid Matter in Boiler Water Foaming. III. Effect of Calcium Carbonate and Magnesium Hydroxide Precipitated inside the Boiler. C. W. FOULK and H. C. BRILL. Ind. Eng. Chem., 27: 12, 1430-5, 1935. Under conditions of tests, calcium carbonate precipitated inside boiler (1) by decomposition of calcium bicarbonate, reduced priming; (2) by pumping sodium carbonate solution into

calcium chloride solution, gave inconclusive results; (3) by reversal of (2), increased priming for several hours, but then lost this property. Magnesium hydroxide precipitated inside boiler by pumping magnesium chloride solution into sodium hydroxide solution reduced priming. When precipitated with calcium carbonate in excess of sodium carbonate in boiler, it counteracted tendency of carbonate to increase priming. Authors draw no broad generalization from work here reported.—*Selma Gottlieb.*

Tar Products for Water- and Damp-Proofing. E. O. RHODES and E. H. HYDE. *Ind. Eng. Chem.*, 27: 12, 1408-10, 1935. In water-proofing, tar products are applied as membrane made from plies of tar-saturated cotton fabric or rag felt. Damp-proofing usually refers to application of bituminous primers followed by heavier bituminous paints or hot moppings of melted bitumens. Applications to water works and swimming pool construction are discussed.—*Selma Gottlieb.*

A Comparison of Several Electrometric and Nephelometric Methods for the Estimation of Small Amounts of Chloride. N. HOWELL FURMAN and GEORGE W. Low, Jr. *Jour. Am. Chem. Soc.*, 57: 9, 1588-91, 1935. From study of three electrometric and two nephelometric methods for estimating small amounts of chloride, it is concluded that electrometric methods are more accurate, easier to perform, less time-consuming, and in general, more satisfactory. Range covered was 0.8 to 44 mg. of chloride per liter.—*Selma Gottlieb.*

Ferrous Metallurgy. ERLE G. HILL. *Ind. Eng. Chem.*, 27: 6, 611-6, 1935. An historical review is given. Future progress necessitates improvements in basic processes for large-tonnage, low-priced steels, such as reduction of sponge iron from ore, better contact between metal and slag, continuous instead of batch smelting, and rolling from liquid metal.—*Selma Gottlieb.*

Alkali Industry. HARALD AHLQVIST. *Ind. Eng. Chem.*, 27: 6, 627-31, 1935. American alkali industry shows marked stability in financial situation and labor relations and steady demand during depression. SOLVAY process, most widely used, requires divisions for lime burning, ammonia absorption, carbonating, drying and calcining, and ammonia recovery. Soda ash is main product, others including caustic soda, refined bicarbonate of soda, modified soda, super alkali and calcium chloride. Caustic soda produced with chlorine in electrolytic process now comprises 40 percent of all caustic made. Relatively small quantity of soda is made from natural alkaline brines in California. Former concentration of soda manufacture around Great Lakes is yielding to new establishments on Gulf and Pacific coasts.—*Selma Gottlieb.*

Cement Progress and Research. R. W. CARLSON. *Ind. Eng. Chem.*, 27: 6, 638-40, 1935. Progress to date includes control of uniformity, increased fineness and lower cost, with greater strength, homogeneity, impermeability, and casting properties of concrete. Volume change and brittleness stand in way of full utilization of concrete strength, engineers consequently resorting to inefficient types of structures. Volume changes of concrete are due to

seasonal temperature variations, heat of hydration of cement, and drying of concrete. Desired cement would combine high efficiency, low thermal expansion, and low heat of hydration. Future developments call for much chemical, physical, and engineering study.—*Selma Gottlieb.*

Electrical Charges of Activated Carbons. H. L. OLIN, J. D. LYKINS and W. P. MUNRO. *Ind. Eng. Chem.*, 27: 6, 690-3, 1935. Definite relationship was found between intrinsic gas adsorption capacity of a carbon and its cataphoretic velocity while suspended in an aqueous medium of high pH, e.g., pH 11.5. Relationship found suggests method of evaluating carbons from cataphoretic velocity. With shifting pH, cataphoretic behavior indicates changes in sign of charge as well as velocity of movement, yielding two isoelectric points between pH 1 and 5.—*Selma Gottlieb.*

Setting of Portland Cement. W. C. L. HEMMON. *Ind. Eng. Chem.*, 27: 6, 694-9, 1935. No apparent correlation was found between rate of contraction, or of heat evolution, and potential compound composition of cement, although close similarity exists between first two properties. Fineness of cement has little effect on shape of rate of contraction curve, but affects time of attainment of maximum rate. At 80°F., this usually occurred between 8 and 15 hours in samples tested, depending on fineness and probably on chemical composition.—*Selma Gottlieb.*

Applications of Sanitation. EDWARD BARTOW. *Ind. Eng. Chem.*, 27: 8, 859-63, 1935. Sanitation employs wide range of sciences in improving water supplies for drinking and industrial uses, eliminating disease, purifying sewage, etc. General review is given of these topics, as well as of organization of health agencies.—*Selma Gottlieb.*

Cellulated Clay Units. GEORGE A. BOLE. *Ind. Eng. Chem.*, 27: 8, 886-7, 1935. Cellulated clay building units are made by firing bloated mass obtained on adding acid to clay slurry containing dolomite and plaster of Paris. Various uses are suggested, including filter tile. Material is light in weight, can be cut about as easily as wood, and shaped on job.—*Selma Gottlieb.*

Locating Ground Water Free From Iron and Manganese. A. R. GARNOCK and PAUL HANSEN. *Water Works and Sewerage*, 82: 6, 199-204, June, 1935. Because of high manganese and iron content of old well supply in Eau Claire, Wis., and because of consumer prejudice against treatment, search for more suitable ground water supply was made. Wells in glacial deposits of coarse sand and gravel along water courses promised best supplies, but tests showed some of these to be unsatisfactory. Apparently, only original, undisturbed deposits, free from organic matter, gave water free from iron and manganese. Further, aëration appears to take place in these deposits where ground water level is close to the surface, thus causing precipitation of iron when it enters the deposits. Test wells were sunk in region deemed of most promise; one of which, a 12-inch well, 89 feet deep, equipped with 30 foot screen, delivered excellent water at rate of 3 m.g.d. in test extending over 159 days. Draw-down

was 3.5 feet. Hardness is 40 p.p.m. Four wells sunk in this deposit, whose combined capacity is 10 m.g.d., form the new supply which is already reducing incrustation in distribution system. A 1400-foot river crossing, using cast iron pipe with flexible joints, is described.—*H. E. Hudson, Jr.*

A Study of Filtering Materials for Rapid Sand Filters. Part 5. The Sand-Gravel Interface. JOHN R. BAYLIS. *Water Works and Sewerage*, 82: 6, 212-215, June, 1935. Disturbance of the gravel by sand boils at the beginning of a wash is described. Agglomeration of mud balls causes formation of clogged masses which may sink and disturb the gravel. Large areas of mounded gravel are caused by faulty wash water distribution. A more gradual transition of sizes from gravel to sand is believed preferable to present practice, and an equation and example for calculating such grading is given. The 10-mesh screen is suggested as the dividing line between sand and gravel. More attention should be paid to the size distribution of the sand, and a method of calculating mixtures of sands to obtain good grading is given. Experiments on use of high specific gravity material in place of fine gravel gave encouraging results.—*H. E. Hudson, Jr.*

Cleaning Wells with Inhibited Muriatic Acid. Anon. *Water Works and Sewerage*, 82: 6, 218, June, 1935. Manganese dioxide incrustation on well screen was removed with inhibited acid. Cost was low, and original well yield was restored.—*H. E. Hudson, Jr.*

The Chicago Method of Making Chlorine Residual Determinations. T. F. DONAHUE and EDWARD ZIMMON. *Water Works and Sewerage*, 82: 6, 228, June, 1935. A comparator which compensates for turbidity is described. Use of small, square bottles compelled adoption of revised chlorine standards, whose preparation is given.—*H. E. Hudson, Jr.*

A Thirteen Year Record of the Operation of a Municipal Water Department. L. R. BURCH. *Water Works and Sewerage*, 82: 7, 233-236, July, 1935. Itemized cost data on operation of Tucson, Arizona, Water Department are presented graphically and discussed in detail. Efficient management has converted water system from a liability to an asset to the city. Effects of rate increase and of metering are shown.—*H. E. Hudson, Jr.*

Mechanical Filtration of Sewage. PHILIP B. STREANDER. *Water Works and Sewerage*, 82: 7, 252, July, 1935. Various types of mechanical filters for sewage treatment are described. Combination settling and filtration tanks with mechanical washing of filtering material and continuous sludge removal may interest water works men.—*H. E. Hudson, Jr.*

Licensing of Water Works Employees. Anon. *Water Works and Sewerage*, 82: 7, 258, July, 1935. An abstract of committee reports to the A. W. W. A. with discussion. The classification and licensing of water works operators is advocated. Those participating in discussion favor licensing, not, however, unanimously as the committee recommended, and stressed need for schools for operators.—*H. E. Hudson, Jr.*

Decisions Involving Water Service. LEO T. PARKER. *Water Works Eng.*, 88: 12, 681, June 12, 1935. If, without authority, officers of a private water corporation enter into a contract with a city to supply water or service at a specified rate, this contract may be rendered valid and enforceable by acquiescence, or by accepting the benefits of the contract, on the part of the water corporation. While it is true that a municipality cannot legally discriminate in water service rates and charges made between customers of the same class, a contract is valid in which a municipality lawfully agrees either to furnish free water, or to supply water at reduced rates, to certain property owners, if such contract is based upon a valuable consideration. Another important point of law is, that usually a state statute is void which is discriminatory. However, it has been held that a statute which discriminates in favor of municipally owned utilities and against such utilities as are privately owned, is not void. Various courts have held that, irrespective of any special agreement between landlord and tenant, the latter is obligated to pay for the water supplied to him at meter rates either by a municipal, or a water, corporation.—*Lewis V. Carpenter.*

A Small City Improves Its Plant. A. P. KURANZ. *Water Works Eng.*, 88: 12, 674, June 12, 1935. Waukesha found that by drilling their wells 500 feet deeper from a level of 1282 feet they were able to get a much softer water and, in addition, lower their yearly power costs by over \$1000. This saving was obtained because the lower strata delivered a larger quantity of water and by pumping into reservoirs rather than into distribution system they were able to eliminate several existing wells with obsolete equipment. Author lists a number of improvements which have been effected. The plant, while municipally owned, is operated like any other utility.—*Lewis V. Carpenter.*

Community Life in Lakes. R. E. COKER. *Water Works Eng.*, 88: 13, 731, June 26, 1935, and 88: 19, 777, July 10, 1935. Author gives a good general discussion of the microorganisms found in lakes, classifying them according to the three regions of the lake, namely, the littoral, the profundal, and the limnetic. Each region has distinctive groups of organisms, which are described.—*Lewis V. Carpenter.*

Street Space for Water Lines in Relation to Other Utilities. E. W. BREITKRENTZ. *Water Works Eng.*, 88: 12, 730, June 26, 1935. Author feels that water lines do not get due consideration in the allotment of street space. No parallel structure should be permitted within two feet of them. Basing his opinion upon results, which are given, of a questionnaire on location of water lines, author recommends legislation to secure for them a definite allotment of street space.—*Lewis V. Carpenter.*

Operation of a Mutual Water Company. PHILIP B. HASBROUCK. *Water Works Eng.*, 88: 14, 774, July 10, 1935. In California, the Mutual Water Companies are owned by the consumers and water is furnished only to the members and at cost. Delinquent water bills lead to temporary suspension of water service and continued delinquency leads to stock forfeiture. In 1934, cost of water used for irrigation by the Fontana Union Water Company was \$16.31 per

acre foot. Water is delivered to consumers on their land by order and the service is distinctly intermittent. In the 1934 season, maximum daily use of water never ran over 114 percent of the monthly average and minimum was as low as 60 percent.—*Lewis V. Carpenter.*

Underground Water Rights. LEO T. PARKER. *Water Works Eng.*, 88: 15, 836, July 24, 1935. The United States, or a state, may construct works in aid of navigation, in the bed of a navigable water course, which wholly cut off access from riparian land to the water, without incurring any obligation to make compensation. The law of eminent domain takes precedence over riparian ownership. The law is specific in upholding liability in damages when natural water course is changed. Courts also hold that if an owner permits certain advantages of his property to result in benefits to adjacent property for a period of 15 to 21 years, then these advantages, or benefits, cannot be withdrawn and belong forever to the title of the property which is benefited. Recently the courts have rendered decisions which give to the landowner only the reasonable use of percolating waters in his land. The majority of states have adopted this law. The rôle of the law with respect to drilled artesian wells is not applicable with respect to natural water sources, such as springs, natural artesian wells, running streams, and the like. Another rule of law which is important where a municipality digs wells and reduces the capacity of near-by wells, is that anyone who complains that his water is depleted by acts of another, must prove that these acts actually resulted in the depleted water supply.—*Lewis V. Carpenter.*

Effect of Passing River Water Through Chain of Lakes. R. A. THUMA. *Water Works Eng.*, 88: 16, 879, August 7, 1935; 88: 17, 934, August 21, 1935; and 88: 18, 987, September 4, 1935. The St. Paul municipal water supply is secured from the Mississippi River by the way of an 8-mile conduit leading through a chain of four lakes. Sampling points were established (1) where the water leaves the Mississippi River; (2) at Pleasant Lake, where water has completed one-half of its journey to the plant; and (3) at the plant, after water has flowed 4½ miles through a conduit from the last of the lakes. Samples, collected at intervals of 10 to 15 days since 1926, have been analyzed in the laboratory. The St. Paul plant treats 8½ billion gallons yearly and capacity of lakes is about 5 billion gallons. Time of travel from pumping station to plant influent varies from 3 weeks to 3 months. Temperature of the water has the most effect on micro-organisms. Large growths of algae were not present with high bacterial counts. Blue-green algae flourish in summer, tapering off in autumn, when diatoms return. Bacterial counts on agar at 37°C. decrease sharply as water progresses through the lakes, especially in summer. Material reduction of color is observed, except in winter; turbidity persists in autumn and winter. The all-important factor of odor remains practically unaffected either by storage in, or by travel through, the lake system. Chemical changes are indefinite and micro-organisms increase. The author concludes that both losses and gains result from passage into and through the lake system, but that gains probably outweigh the losses.—*Lewis V. Carpenter.*

Some Interesting Leakage Tests. PAUL J. DISHNER. Water Works Eng., 88: 16, 883, August 7, 1935. Author gives some detailed tables showing how the leakage decreased in non-metallic-lead-substitute jointed cast iron pipe of 8- and 12-inch diameters. After pipe was laid, daily readings were taken on leakage until pipe line was accepted. One section of 2812 feet of 12-inch C. I. pipe had initial leakage of 998 gallons per day per inch-mile, which in 49 days had dwindled to 41 gallons. In another 851-foot section of similar pipe, initial leakage of 1301 gallons per day per inch-mile had dwindled at the end of 88 days to 27 gallons. Data on 8-inch C. I. pipe are also given.—*Lewis V. Carpenter.*

Michigan City Builds Plant for Treatment of Lake Water. Anon. Water Works Eng., 88: 17, 932, August 21, 1935. Michigan City, Ind., completed an 8,000,000 g.p.d. rapid sand filter plant, at cost of \$413,000, with P.W.A. funds. Plant has provision for adding coagulant, carbon, chlorine, and ammonia before coagulation, and ammonia, lime, and chlorine subsequent to coagulation or to filtration. Thirty minutes mixing is provided in mechanical paddle type of mixer.—*Lewis V. Carpenter.*

Pipe Line Corrosion. C. M. WICHERS. Chemisch weekblad, 3: pages 38-40, 1936. (Corrosie van gegoten ijzeren buizen in den bodem.) The subject awakes in the Netherlands great interest, as corrosive soils in that country are not rare. Many soils in America may resemble them. The author has closely examined many pipe lines in clay, peat, loam and sand. The soil was analysed chemically and mechanically. The pipes were cleaned with sand sprayer. Prominent factors in corrosion are pH and a biological reduction of sulfates. The latter process takes place in anaerobic conditions (investigated by Beyerink and Von Wolzogen Kühr). The author has stated that this biological reduction, in forming sulphuretted hydrogen and sulfide of iron, may or may not have some injurious effect upon iron, but that an oxidation following this sulfate reduction can be disastrous for iron pipes. In that case the sulphide is oxidised to very acid sulphates of iron. If calcium carbonate is finely distributed in the soil, the corrosion can be prevented by the neutralization of the acid sulphates. Actual or potential concentration of hydrogen ions therefor cannot be standards for corrosive power of soil, if the soil contains sulphates and has little or badly distributed calcium carbonate in it. The latter conditions are always important, as anaerobic and aerobic conditions can easily alternate in most soils and as sulfate reducing bacteria are practically omnipresent. The Dutch Corrosion Board, working in other areas and with other methods, has confirmed these statements of the author. Finally the author has found that clay, loam or loamy sand, when in plastic condition brought closely all round the pipes, restrains corrosion, as circulation of water (electrolytes, acid) and of oxygen is practically prevented in such fine and tight media. These conclusions resulted from examination of existing works.

NEW BOOKS

Flood Discharges in the United States: Magnitude and Frequency. U. S. Geological Survey, Water Supply Paper 771, 1935. By CLARENCE S. JARVIS and Others. Government Printing Office, Washington, D. C.

To the long list of the useful publications of the U. S. G. S. is here added another which is bound to find its place on the shelf of every engineer or engineering organization interested in river discharge. It is an assembly and tabulation of flood discharge figures for rivers over the entire United States which heretofore have been widely scattered in the Survey's publications on individual rivers, accompanied by notes, explanations and discussions of methods for estimating flood flows.

The compilation of the work was sponsored by the Mississippi Valley Committee and its successor, the Water Planning Committee of the National Resources Board, and undertaken with the cooperation of the Committee on Flood Protection Data of the A. S. C. E. and a committee representing the American Geophysical Union. Names of well known authorities, such as Thorndike Saville, Robert Horton and Merrill M. Bernard appear under the headings of special chapters.

The main part of the book is naturally the tabulation of flood discharges of about 200 river gauging stations distributed over the continental United States as shown on an attached map. A glance at this map shows that some parts of the country are covered much better than others. The scarcity of data for the South Atlantic-East Gulf area and the western tributaries of the Mississippi is especially noticeable. It is to be regretted that rivers like the middle and lower Connecticut, the Catawba-Santee, Savannah and Alabama, which are of considerable importance for water supply and power are not covered at all. In the Middle West the lower Kansas River is amply reported on with seven stations, while data on the Platte, Arkansas and Red Rivers are omitted except for a few points on the headwaters of the first two. Correlation of the map and the data would be greatly facilitated if the gauging points on the map were referenced with numbers or names.

The data are presented in the form of tables giving the full record of gauge heights and discharges above a certain arbitrary minimum in chronological order. Each tabulation is preceded by the pertinent data about gauge location, size of drainage area, length of record, source and reliability of data. Greatly to be commended is the clear distinction made between daily (midnight to midnight average) peak and momentary peak, with emphasis placed on the former. The relation between the two is discussed in a special chapter.

It is somewhat of a question to this reviewer whether the discussion of statistical methods of forecasting flood flows merits all the space given it in the volume. The multiplicity of methods and variations described, Professor Saville's final statement that "none of the methods thus far presented for estimating frequency of flood magnitude offers more than an approximation for the guidance of the engineers' judgment" and Professor Slade's conclusion that—"the statistical method—is an entirely inadequate tool in the determination of flood frequencies," seem to indicate that such methods at present are of very limited usefulness.

That they should be considered only when combined with a careful study of hydrological conditions as affecting a certain drainage area is the point made by Mr. Horton in the next chapter, in which the influence of such conditions as affecting run-off is aptly described. A map showing locations and rainfall contours of some recorded storms of exceptional intensity (such for instance as published on pages 150 to 180 of Part V of the Technical Reports of the Miami Flood Conservancy District) would add to the emphasis and usefulness of this and more yet of the next chapter in which Mr. M. M. Bernard explains the Unit Hydrograph method of estimating floods. This method seems to be the most logical one devised so far, inasmuch as it depends on actual meteorological occurrences and not on the interpretation and interpolation of statistical curves. It may have to be treated with caution for very large drainage areas, but an essentially similar approach has been found to give reasonable results on the lower Susquehanna for an area of over 25,000 square miles.

The usefulness of the volume is enhanced by a glossary of standard terms and an extensive bibliography.—*Paul E. Gisiger.*

Proceedings 9th Annual Conference Maryland-Delaware Water and Sewerage Association, Annapolis, Maryland, May 16 and 17, 1935. 6 x 9 inches. A. W. Blohm, Secy.-Treas., 2411 North Charles Street, Baltimore, Maryland. **The Annapolis Garbage Incinerator.** H. L. HOUSTON. 1-15. Description of preliminary studies, selection of location, and detailed specifications of plant. **Comprehensive Plans for Water Supply and Sewage Systems in Maryland.** J. R. McCOMAS. 16-24. Plans for water supply should be expressed in terms of available sources, ultimate yield and quality, necessary treatment, transmission, and location and characteristics of pumping stations, storage units, and distribution system. Plans for sewerage should represent method, whether separate or combined sewers, controlling sizes, grades and locations, location of treatment plant site, type of treatment, and extent to which treatment operation should be carried. Zoning is an important element in the development of comprehensive planning. **Review of Short School.** E. S. HOPKINS. 25-27. Informal discussion concerning course at University of Maryland. **The Methods for Testing of Materials for Use as Salt Water Pipe Lines in the Naval Service.** W. C. STEWART. 28-66. Detailed results of the effects of water velocities, jet impingement, turbulence occasioned by valves and fittings, and stray electrical currents upon various alloys of copper, brass, nickel, zinc, silver, aluminum, tin, chromium, iron, and steel under service conditions and with types of pipe and joints suitable for naval use. **The Pines-on-the-Severn Water Plant.** W. C. MUNROE. 67-73. Description of practical water supply development for sparsely populated, seasonal, recreational community, secured at cost of about \$20.00 per consumer per year. **Interesting Experiences with Microorganisms in the Wash Water Supply.** G. E. HARRINGTON. 74-86. Report of an experience with *synedra ulna* at Dalecarlia Lake during a period of seven days. Application of large excesses of alum, sulphuric acid, lime, copper sulphate and ammonia, at a cost of about \$1750, was found necessary. Discussion recalled comparable experiences in Baltimore supply. **The New Water Purification Works at Burnt Mills, Maryland.** R. B. MORSE. 87-105. Description of new circular steel plant, of

5-m.g.d. capacity, placed in operation in May, 1934. Various elements of the plant are arranged as annual rings about a central pipe vault. Actual cost as built was at rate of about \$10,000 per m.g.d. **Use of Water for Air Conditioning and Refrigeration.** A. R. McGONEGAL. 106-110. Use of water for cooling purposes without re-circulation will place an enormous burden upon public water supplies if developed along trends now apparent. Danger of cross-connections incorporated in such installations is also imminent. **The Design of Moore's Run Interceptor Sanitary Siphon Under Herring Run Valley, Baltimore, Maryland.** F. H. FIROVED. 111-123.—R. L. McNamee.

The Biology of the Iron and Manganese Cycle. P. DORFF. 116 pages, 32 illustrations, price: bound RM \$7.50. Published by Verlagsgesellschaft für Ackerbau m.b.H., Berlin SW. 11, Germany.

The work described was carried out partly in the Biological Department of the Prussian State Institute for Water, Soil and Air Hygiene in Berlin-Dahlem and partly at the University of Lund in Sweden. Part I deals with the iron cycle. Both the regional occurrence of iron-depositing bacteria and the types of waters in which they occur in Småland and Northern Germany are described and compared. Samples of iron from the tropics and South-Eastern Europe are also discussed. Numerous varieties of these bacteria are of very wide occurrence. In the micro-zones formed by these bacteria in the different layers of mud deposits, a large number of different varieties are contained; a table is given showing the rarer of these iron bacteria. The chemical processes involved in the bacteriological oxidation of iron carbonates are described. A satisfactory solution of the problem of bacteriological oxidation of humates has not yet been found. In another section the technique used in research work on iron-depositing bacteria, especially the preparation of cultures (glass slides) is discussed in detail.

The section on lake and swamp iron ores contains a short description of the formation, chemical composition, distribution and exploitation of such ore deposits. Special mention is made of the districts in which the author made his studies. A geological map of the floor of a Swedish lake serves to demonstrate the conditions under which the iron deposits are formed. Of special interest to those concerned with the operation of water works and mineral springs is the description of the results of the activity of such iron and manganese depositing organisms.

The author concludes with a discussion of the nonbiogenic formation of iron and manganese deposits, with special reference to pan formation in soils, to which many crop failures are due. The book is provided with an exhaustive bibliography containing 305 references to the current scientific literature up to 1935.